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PHASE 1 INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM

UPPER YELLOWSTONE BASIN
GLACIER LAKE DAMS
CARBON COUNTY, MONTANA
MT-68 (NORTH DAM)
MT-1446 (SOUTH DAM)

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PREPARED FOR:

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GOVERNOR, STATE OF MONTANA

MONTANA DEPARTMENT OF NATURAL RESOURCES & CONSERVATION
(OWNER)

ROCK CREEK WATER USERS ASSOCIATION
(OPERATOR)

PREPARED BY:
HOSKINS-WESTERN-SONDEREGGER, INC.

APRIL, 1981

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EXECUTIVE SUMMARY

Under contract with the Seattle District Corps of Engineers and with representation from the State of Montana Department of Natural Resources and Conservation, Glacier Lake North Dam and Glacier Lake South Dam were inspected by Hoskins-Western-Sonderegger, Inc., on 17 September 1979, under the authority of Public Law 92-367. The Glacier Lake Dams are located in Carbon County, Montana, approximately 19 miles southwest of Red Lodge, Montana.

This report was compiled from information obtained during an on-site inspection, a review of operation records, and analysis of hydrologic and hydraulic data. Findings were compared to engineering criteria currently accepted by most private and public agencies engaged in dam design, construction, and operation.

PRINCIPAL FINDINGS AND EVALUATIONS

Glacier Lake is operated under a U.S. Forest Service special-use permit. It is used primarily for irrigation storage and secondarily for recreation. The project consists of a natural lake and two embankments which raised the lake elevation for irrigation storage. The reservoir has a drainage area of approximately 3.4 square miles, surface area of approximately 151 acres at normal pool, and total storage at the minimum dam crest of approximately 4980 acre-feet.

In accordance with the "Recommended Guidelines for Safety Inspection of Dams" (Ref. 1), the 57-foot-high Glacier Lake North Dam (MT-68) and the 20-foot-high Glacier Lake South Dam (MT-1446) are both classified as being of intermediate size. Because more than 50 inhabitable structures below the dams could be affected by a dam breach, the project is classified as having a high (Category I) downstream hazard potential.

Inspection criteria (Ref. 1) recommend that an intermediate-sized project with a high downstream hazard potential be capable of safely handling a flood equal to the Probable Maximum Flood (PMF). The PMF is the flood expected from the most severe combination of meteorologic and hydrologic conditions that are reasonably possible in the region.

During the dam safety analysis, an estimated PMF resulting from a 24-hour Probable Maximum Precipitation (PMP) storm was developed for the drainage basin. The resulting PMF has a volume of approximately 3390 acre-feet. The reservoir level at the beginning of the 24-hour storm was assumed to be at the spillway crest elevation of 9812.0 feet to account for antecedent storm conditions. Reservoir routings of the estimated PMF indicate that the project will handle approximately 45% of the PMF volume before overtopping if the low-level outlet is fully closed, or approximately 50% of the PMF volume with the outlet fully open. The dams are constructed of materials which may erode and fail when overtopped by floodwaters. Such failure would endanger the lives of many people and cause extensive property damage.

On the basis of the field inspection and the preliminary study of hydrologic and operational data, the Glacier Lake project does not conform to the recommended guidelines with respect to discharge and/or storage capacity to safely handle the recommended SDF.

Evidence of slight seepage was found at the downstream toe of the South Dam and in the left abutment trough of the North Dam. Considerable seepage flow was found in the right abutment trough of the North Dam and in the low-level outlet tunnel. This seepage poses no threat to the embankment at this time due to the free-draining rock embankment and the stable rock foundation. No piezometers are installed in either embankment to measure water levels, and there is no internal system of drains in the embankments or the foundations; however, the lack of piezometers or a designed drain is not essential because the embankments are constructed of free-draining materials. Conditions described in this report suggest that the embankments conform to the recommended guidelines (Ref. 1) with respect to the stability of the upstream and downstream slopes although formal stability analyses are lacking.

PRINCIPAL RECOMMENDATIONS

Due to the availability of storage between the normal pool and the dam crest, the present project provides a degree of flood protection to the downstream area. The intent of report recommendations is to maintain or improve project safety, if feasible, without decreasing this existing flood protection.

Develop and immediately place into operation a downstream warning plan, for use in the event of possible dam overtopping and/or failure. Repair spalling concrete in the upstream facing of the dams. Conduct more-detailed hydrologic and hydraulic routing studies to better determine the downstream hazard and required spillway capacity. Modify the project as studies indicate. Conduct and place on file stability analyses for the dams.

Prior to performing engineering studies and remedial construction, coordinate all work with the U.S. Forest Service and the State of Montana Department of Natural Resources and Conservation to insure compliance with all pertinent laws and regulations.

Stephen H. Nickel
Professional Engineer

PERTINENT DATA

1. GENERAL

Federal Identification Number	MT-68 (North); MT-1446 (South)
Owner	State of Montana Department of Natural Resources and Conservation
Operator	Rock Creek Water Users Association
Purpose	Irrigation
Location	Township 9 South, Range 18 East Carbon County, Montana
Watershed	Rock Creek
Downstream Hazard Potential	High
USGS Quadrangle (15-minute series)	Alpine, Montana Beartooth Butte, Wyoming

2. RESERVOIR

Surface Area at Normal Pool (Spillway Crest)	151 acres
Normal Storage (Spillway Crest)	4200 acre-feet
Total Controlled Storage (Min. Dam Crest)	4980 acre-feet (North) 2850 acre-feet (South)
Surcharge Storage	780 acre-feet
Drainage Area	3.4 square miles
Reservoir Water Surface Elevation (9/17/79)	9811.2 feet (NGVD)

3. SPILLWAY

Type	Uncontrolled, excavated rock channel with concrete weir
Crest Elevation	9812.0 feet (NGVD)
Crest Width	82 feet
Spillway Capacity (Min. Dam Crest)	2650 cfs

4. OUTLET WORKS

Type	Excavated rock tunnel
Controls	48-inch x 48-inch vertical slide gate with controls located on dam crest
Size	6.5 feet high by 5.5 feet wide (approx.)
Length	120 feet
Inlet Invert	9780.0 feet (NGVD) (estimated)
Outlet Invert	9779.5 feet (NGVD)
Normal tailwater	Not applicable
Discharge Capacity (Min. Dam Crest)	472 cfs

5. DAM

	MT-68 North	MT-1446 South
Type	Rockfill with concrete upstream face	Rockfill with concrete upstream face
Hydraulic Height	57 feet	20 feet
Crest Length	230 feet	253 feet
Minimum Crest Elevation	9817.0 feet (NGVD)	9817.1 feet (NGVD)
Crest Width	10 feet	10 feet
Upstream Slope	1(V) on 1(H)	1(V) on 1(H)
Downstream Slope	1(V) on 1.5(H)	1(V) on 1.5(H)
Size Classification	Intermediate	Intermediate

Note: All elevations are referenced from the spillway crest elevation of 9812.0 feet shown on the State Water Conservation Board construction plans. Datum is the National Geodetic Vertical Datum (NGVD).

CHAPTER 1

BACKGROUND

1.1 INTRODUCTION

1.1.1 Authority and Scope

This report summarizes the Phase I inspection and evaluation of the Glacier Lake Dams, owned by the Montana Department of Natural Resources and Conservation.

The National Dam Inspection Act, Public Law 92-367 dated 8 August 1972, authorized the Secretary of the Army, through the Corps of Engineers, to conduct safety inspections of non-federal dams throughout the United States. Pursuant to that authority, the office of the Chief of Engineers issued "Recommended Guidelines for Safety Inspection of Dams" (Ref. 1) in May of 1975.

The recommended guidelines were prepared with the help of engineers and scientists, highly experienced in dam safety, from many federal and state agencies, professional engineering organizations and private engineering consulting firms. Consequently, the evaluation criteria presented in the guidelines represent the comprehensive consensus of the engineering community.

Where necessary the guidelines outline a two-phased study procedure for investigating and evaluating existing dam conditions so deficiencies and hazardous conditions can be readily identified and corrected. The Phase I study is:

(1) a limited investigation to assess the general safety condition of the dam;
(2) based upon an evaluation of the available data and a visual inspection;
(3) performed to determine if any needed emergency measures and/or if additional studies, investigations and analyses are necessary or warranted; and
(4) not intended to include extensive explorations or analyses, or to provide detailed alternative correction recommendations.

The Phase II investigation includes all additional studies necessary to evaluate the safety of the dam. Included in Phase II, as required, should be additional visual inspections, measurements, foundation exploration and testing, material testing, hydraulic and hydrologic analyses and structural stability analyses.

The authority for the Corps of Engineers to participate in the inspection of non-federally owned dams is limited to Phase I investigations with the exception of situations of extreme emergency. In these cases the Corps may proceed with Phase II studies but only to the extent needed to answer serious questions relating to dam safety that cannot be answered otherwise. The two phases of investigations outlined above are intended only to evaluate

project safety and do not encompass in scope the engineering required to perform design or corrective modification work. Recommendations contained in this report may be for either Phase II safety analyses or detailed design study for corrective work.

The responsibility for implementation of these Phase I recommendations rests with the State of Montana. It should be noted that nothing contained in the National Dam Inspection Act, and neither any action nor failure to act under this act shall be construed (1) to create liability in the United States or its officers or employees for the recovery of damage caused by such action or failure to act or (2) to relieve an owner or operator of a dam of the legal duties, obligations, or liabilities incident to the ownership or operation of the dam.

1.1.2 Purpose

The purpose of the inspection and evaluation is to identify conditions that threaten public safety, so that they may be corrected in a timely manner by non-federal interests.

1.1.3 Inspection

The findings and recommendations in this report were based on a visual inspection of the project, a brief engineering analysis, and an interview with the owners. Construction plans for the facility were supplied and used in the analysis. Inspection procedures and criteria were those established by the "Recommended Guidelines for Safety Inspection of Dams" (Ref. 1).

Personnel present during the inspection included:

Louis Boitano, Civil Engineer, Seattle District Corps of Engineers;
Art Taylor, Civil Engineer, State of Montana, Department of Natural Resources and Conservation; and
Earl Zumbrun, representing the Rock Creek Water Users Association.

Hoskins-Western-Sonderegger, Inc. (HWS) personnel who participated in the field inspection and contributed to this report are:

Stephen Nickel, Geotechnical Engineer, Team Leader;
Mike McMeekin, Hydrologist/Hydraulics Engineer; and
Gene Holtorf, Hydrologist/Hydraulics Engineer.

This report has been reviewed by representatives of the Montana Department of Natural Resources and Conservation, the Rock Creek Water Users Association, and the U.S. Forest Service. Written comments are included in the Appendix of this report. The Rock Creek Water Users Association did not comment.

1.2 DESCRIPTION OF PROJECT

1.2.1 General

Glacier Lake is a high mountain lake owned by the Montana Department of Natural Resources and Conservation. The lake and dam are located in the Custer National Forest and are operated under a U.S. Forest Service special-use permit. The main purpose of the project is to store snowmelt and rainfall runoff for irrigation during the following growing season. Recreation is a secondary use.

Glacier Lake is located on Rock Creek in T9S, R18E, in Carbon County, Montana, approximately 19 miles southwest of Red Lodge, Montana. The natural storage capacity of Glacier Lake, which is unknown, was increased with the construction of Glacier Lake North Dam (MT-68) and Glacier Lake South Dam (MT-1446), completed in 1937. The lake has a drainage area of approximately 3.4 square miles and a surface area of approximately 151 acres at the normal pool elevation of 9812.0 feet. The spillway, located in the common abutment between the two dams, is an uncontrolled rock channel discharging to Rock Creek over a low concrete weir. The low-level outlet is a blasted rock tunnel beneath the North Dam, which is approximately 6.5 feet high by 5.5 feet wide. The outlet is controlled by a 48-inch x 48-inch rectangular slide gate. The operating controls are in a wooden gate house, located on the crest of the North Dam.

The North and South Dams are 57 feet high and 20 feet high, respectively, and at the minimum dam crest elevation of 9817.0 feet, control 4976 acre-feet and 2849 acre-feet, respectively. Based on a visual reconnaissance and engineering judgment, 3 campgrounds and more than 50 cabins or houses along Rock Creek could be affected by a sudden breach of either dam. The dams, therefore, are classified as being intermediate in size and as having a high downstream hazard potential.

1.2.2 Regional Geology

Glacier Lake is in the heart of the Beartooth Mountains on the Montana-Wyoming border. Its name aptly describes its origin in that Pleistocene alpine glaciation has been the most recent geological event to change the surficial features of the Beartooth Mountains.

Before the late Cretaceous, the Northern Rocky Mountain region was an area of quiet basinal sedimentation. Approximately 100 million years ago, during the Cretaceous Epoch, the area became geologically active. Three geologic events took place: (1) uplift of the Central Montana Arch; (2) Late Cretaceous thrust faulting; and (3) Late Cretaceous-Tertiary igneous activity.

The rock type that predominates in the area is the Pre-Beltian suite of rocks that are Precambrian in age. Most of the younger sedimentary and metamorphic rocks have been eroded away in this area of the Northern Rocky Mountains, exposing the Precambrian surface.

Pleistocene glaciation, beginning about 3 million years ago, brought still more change to the Beartooth Mountains. Increased precipitation in the mountainous portions of the area exceeded summer melting, and, as a result, the snow accumulated to form glaciers which covered most of the high mountain peaks. Glacier Lake is the present surficial remnant expression of the glacier that gouged out the Rock Creek valley during the Pleistocene Epoch.

1.2.3 Seismicity

Glacier Lake North Dam (MT-68) and Glacier Lake South Dam (MT-1446) lie intermediate between Seismic Zones 2 and 3 as indicated by the Seismic Zone Map (Ref. 1). The seismic probability of this regional setting is one of potential for moderate to major damage and is based on the known distribution of damaging earthquakes in the region.

Glacier Lake is located in the eastern portion of the geologically stable region of the Beartooth Uplift. No major faults have been mapped in the vicinity of the lake. Adjacent to the western extent of the Beartooth Uplift, the "Preliminary Map of Young Faults in the United States" (Ref. 2) shows intensive Quaternary faulting in the northwestern corner of Wyoming and Holocene displacement on the western slopes of the Absaroka Range, to the west of the Beartooth Range.

Local earthquakes large enough to be reported in References 3 and 4 occur to the west-southwest of Glacier Lake, in northwest Wyoming, southeast Idaho, and the adjoining areas of Montana. Two earthquakes of significant intensity which have occurred in this seismically active tri-state region were the Hebgen Lake, Montana, earthquake (8 August 1959), that had an intensity of X (Modified Mercalli), and another southeast of Dillon, Montana, that had an intensity of VIII (23 November 1947).

In the area bounded by the 110th and 112th meridians and by the 44th and 46th parallels (including the tri-state region), there have been 57 reported earthquakes with intensities of V and 10 earthquakes with intensities of VI in this century (Ref. 3 and 4). Glacier Lake is 25 miles directly east of this seismically active area.

1.2.4 Site Geology

Glacier Lake occupies the upper reaches of a Pleistocene glacio-valley. The western side of the lake is bounded by a very steeply sloped (60% to 80%) cirque headwall. Moderately scoured glacial troughwalls with concave slopes are present on the remaining sides. Tarns are present both upstream and downstream of the lake. A thin soil mantle (regolith) is present on top of a metamorphic bedrock. Mainly rockland with thin till deposits and mass-wasting features are present at isolated areas near the lake. The soils are very shallow, well-drained sandy loams, that are very rocky. The dams forming the present impoundment appear to have been constructed directly on the bedrock, which is fractured and jointed.

1.2.5 Design and Construction History

According to DNRC and Forest Service records, the Glacier Lake Dams were completed in 1937. Funds were obtained by grants from the Montana State Water Conservation Board and the PWA and by a PWA loan. The original plans (See Plates 2 and 3) show the embankments to have been rockfill structures with a thin hand-placed upstream zone under a concrete upstream facing. The plans show grout holes beneath the toe of the facing. It is not known whether any grouting was performed. The details of the low-level outlet, including a trash rack, are shown on Plate 3. The actual tunnel size is somewhat larger than that which is shown on the plans, and the concrete bottom lining shown extends only 3 feet downstream of the gate structure. The South Dam apparently was not built according to plans, in that the plans show it to be straight, but it was built containing a bend at about its midpoint (see Photos 6 and 7).

CHAPTER 2

INSPECTION AND RECORDS EVALUATION

2.1 HYDRAULICS AND STRUCTURES

2.1.1 Spillway

The spillway for Glacier Lake is located in the common abutment between the North and South Dams. The spillway is a rock channel, as seen in Photos 13 through 15. Approximate dimensions and elevations were determined in the field for use in the calculation of the discharge capacity of the spillway.

There are two sections of the spillway channel which function as control sections. For flows from 0 cfs to approximately 700 cfs, the control section is the 82-foot-long concrete weir located at the crest of the spillway, on the extended centerline of the South Dam. For flows greater than 700 cfs, the control shifts to a section located approximately 32 feet downstream from the crest. The slope of the channel between these two sections is about 7.5%. The width of the spillway channel at the downstream control section is approximately 25 feet. The spillway channel slope downstream from the downstream control section is in excess of 1(V) on 0.66(H). A cross section of the crest along the weir centerline is shown on Plate 4. The spillway profile and a cross section of the downstream control section are shown on Plate 4-A.

The discharge rating curve for the spillway was computed by assuming critical depth at the downstream control section and computing water surfaces profiles upstream into the reservoir, using a Manning's "n" of 0.04. The discharge capacity of the spillway varies from 0 cfs at the normal pool elevation of 9812.0 feet to 2650 cfs at the minimum dam crest elevation of the North Dam, 9817.0 feet. The discharge rating curve for the spillway is shown on Plate 6.

2.1.2 Outlet Works

The low-level outlet for Glacier Lake is located at approximately Station 0+70 of the North Dam. The low-level outlet consists of a rock tunnel, which is approximately 6.5 feet high and 5.5 feet wide (see Photos 10, 11, and 12). The tunnel was formed by blasting in sound metamorphic rock. The tunnel is unlined, except for a 4-foot-long, 4' x 4' formed concrete section on the downstream side of the vertical control gate. The concrete in the floor of the tunnel extends an additional 3 feet downstream. The discharge through the low-level outlet is controlled by a 48-inch x 48-inch vertical slide gate in a wet well near the tunnel's midpoint (see Plate 3). The control mechanism for the gate is located in a wooden gate house on the dam crest (see Photos 8 and 9). At the time of the inspection, the gate was in a closed position, but there was approximately 0.5 cfs leaking around the gate.

The inlet end of the tunnel was under water, and inspection of the inlet structure and trash rack was not possible. The tunnel and its outlet, as seen in Photos 10, 11, and 12, are in good condition. The concrete in the concrete-lined section shows minor surface erosion. DNRC inspection reports indicate that there has been a problem with erosion of the tunnel floor at the downstream end of the concrete-lined section. Rocks have been fitted into an erosion pocket at that location in an attempt to control undermining of the concrete slab. High flows through the gate could cause additional problems in this area.

The rock through which the outlet tunnel is cut has primary joint patterns with strikes roughly parallel with the tunnel axis and dips of approximately 20 degrees to the north and 70 degrees to the south. Joint spacing in both directions is predominantly between 6 inches and 2 feet. The tunnel floor slopes irregularly toward the north. There is no visible weathering of the rock in the tunnel and no significant erosion of the tunnel outlet. The tunnel outlet is 8 to 10 feet above the streambed (see Photos 2 and 10); however, there is no evident erosion of the rock below the outlet.

The capacity of the conduit was computed to be approximately 438 cfs at the normal pool elevation and approximately 472 cfs at the minimum dam crest elevation. A partial discharge rating curve is shown on Plate 7.

2.1.3 Freeboard

The effective fetch for wind-generated waves is 1700 feet, and the wave run-up and set-up on the embankment is estimated to be 2.3 feet for both the North and South Dams (Ref. 5). A 5-foot vertical difference exists between the minimum dam crest elevation of 9817.0 feet and the normal pool elevation of 9812.0 feet. This vertical distance is considered adequate in preventing wave overtopping under normal pool conditions (Ref. 6).

Routings indicate that dam overtopping occurs during the PMF; therefore, no freeboard exists during the recommended spillway design flood.

At the time of inspection, the lake was at elevation 9811.2 resulting in a 5.8-foot vertical distance, which is more than adequate in preventing wave overtopping.

2.2 HYDROLOGY

2.2.1 Climatology and Physiography

The climate of the area around Glacier Lake is continental and characterized by a large daily and seasonal temperature range. Extreme variability of wintertime temperatures results from the frequent occurrence of chinook winds which follow a Pacific maritime air mass invasion.

The summers are characterized by warm days with low humidity and cool nights. Winters are cold and highly variable in severity from year to year and within a given year.

Red Lodge, in Carbon County at an elevation of 5570 feet, is the climatological station nearest the project site. The precipitation and climatological data available from this station are not applicable to the project because of a 4242-foot elevation difference between Glacier Lake and the weather station. There is a National Weather Service precipitation gauge at the trailhead, approximately 1 mile east of the lake. However, precipitation data from the gauge also are not applicable to the lake because of a nearly 1100-foot elevation difference. The average annual precipitation at Glacier Lake, as estimated from Soil Conservation Service graphs, is over 50 inches (Ref. 7). At the project site, the expected date of the first freeze is August 18th, and the expected date of the last freeze is July 19th (Ref. 8).

Glacier Lake Dams are located on the main fork of Rock Creek, in the Beartooth Mountains and Custer National Forest. The drainage basin above and including Glacier Lake has an area of approximately 3.4 square miles, about 151 acres of which is water surface area. Basin elevations range from the normal pool elevation of 9812 feet to 12,250 feet at the top of the Beartooth Plateau. The average ground slope is about 23%. Basin vegetation consists of moderately thick pine and grasses in the lower basin area to sparse pine and rocky surfaces in the upper basin area (see Photo 1).

2.2.2 Reservoir Storage and Spillway Discharge

The reservoir has a surface area of approximately 151 acres and controlled storage of approximately 4200 acre-feet at the spillway crest elevation of 9812.0 feet. Storage of approximately 776 acre-feet is available between the spillway crest and the minimum crest elevation of the North Dam, 9817.0 feet. The total discharge for the spillway at the minimum dam crest is approximately 2650 cfs. The discharge capacity of the facility would increase an additional 472 cfs if the low-level outlet were completely open.

2.2.3 Estimated Probable Maximum Flood

The probable maximum flood (PMF) is defined as the flood expected from the most severe combination of critical meteorologic and hydrologic conditions that are reasonably possible in the region. A storm, the intensity of which approached the probable maximum precipitation (PMP) intensity,did occur in parts of Montana in June 1964.

A PMP storm of 24-hour duration was applied to the basin. The 24-hour, 6-hour, and 1-hour PMP depths were estimated from National Weather Service Technical Paper 38 (Ref. 9) to be 18.8 inches, 13.6 inches, and 8.3 inches, respectively. All 6-hour increments from 0 to 24 hours were arranged in accordance with criteria in Weather Bureau Hydrometeorological Report No. 43 (Ref. 10).

The PMF was assumed to result from a PMP storm in the late spring over frozen ground. A constant soil loss rate of zero was, therefore, applied throughout

the 24-hour PMP storm in accordance with Corps of Engineers recommendations. The overall configuration of the 24-hour storm is not affected by soil losses, and the basin rainfall is equal to the basin runoff for all storm increments. Direct precipitation onto the surface of the lake was also added with no losses.

2.2.4 Flood Routing

A flood routing of the PMF was made to determine the portion of the PMF that could be handled by reservoir storage and spillway discharge capacity before overtopping. For routing the PMF through Glacier Lake, the lake level at the beginning of the PMF was assumed to be at the spillway crest elevation of 9812.0 feet, which would correspond to the normal pool condition. The total volume of the 24-hour PMF for Glacier Lake is approximately 3390 acre-feet with a peak flow rate of approximately 33,490 cfs. The routings indicated that with the control gate of the low-level outlet closed, the project will handle, through storage and spillway discharge, approximately 45% of the PMF volume before the dams are overtopped. With the control gate completely open, the project will handle approximately 50% of the PMF volume before the dams would be overtopped.

The PMF inflow hydrographs were developed using the SCS dimensionless unit hydrograph. These hydrographs were generated and combined using the HEC-1 (Dam Safety Version) computer program (Ref. 11). The reservoir routing of the PMF was made using the Modified Puls method contained in the HEC-1 program.

2.3 GEOTECHNICAL EVALUATION

2.3.1 Embankments

The 57-foot-high rockfill North Dam is 230 feet long and has a crest width of 10 feet. The 20-foot-high rockfill South Dam is 253 feet long and has a crest width of 10 feet. The upstream slopes of both dams are 1(V) on 1(H). The downstream slopes are 1(V) on 1.5(H). Design details can be seen on Plate 3. Borrow for the embankment appears to have been obtained locally; however, a borrow area was not readily visible. Records show that at least a portion of the material for the dam was brought to the site by a cableway having a 1500-foot rise. The material exposed on the crests of both dams is angular, broken rock, ranging from about 2 inches to about 10 inches in diameter. This material will erode under sustained overtopping flows. The upstream faces of both dam embankments are faced with reinforced concrete. The construction plans (Plate 3) show the concrete facing slabs to be keyed into bedrock and founded on a bed of hand-placed, free-draining rock. The concrete is shown to be 12 inches thick at the toe, tapering to 6 inches thick at the top. The existing concrete surface shows that the upper surfaces of the slabs were individually formed and that the slabs were probably continuously placed. The plans indicate that the joints between slabs were to have been filled with corrugated, asphalt-dipped, metal strips with tarred felt strips on one side and backed with a small reinforced concrete strip. Some of the joints have been repaired with cement or epoxy grout. There is no evidence, on the dam crest, of the reinforced concrete

backing strips. The rock comprising the embankments appears to be of metamorphic origin. There were no noticeable sags or bulges on any of the surfaces of the embankments. There is no vegetation on the embankments.

2.3.2 Foundation Conditions, Seepage, and Drainage

The two embankments appear to be founded directly on bedrock. The bedrock at the project site is fractured and jointed and is relatively permeable along joints or fractures. However, the rock is highly insoluble and no increase in flow rate with time is anticipated. Grouting at the upstream toe of the embankments was shown on the plans as an engineer's option during construction. It is not known whether any grouting was performed. The upstream concrete facing appears to be performing adequately.

No free water was found at or below the toe of the South Dam; however, green grass at the downstream toe was evidence of probable slight foundation seepage.

There were two concentrated seeps at or immediately below the downstream toe of the North Dam. One of these was at the right side of the outlet tunnel, about 4 feet above the top of the tunnel. The other was about 20 feet right of the first and about 15 feet higher. These locations can be seen in Photos 10 and 16, respectively. The combined flow from these two seep areas was estimated to be about 0.5 cubic feet per second (cfs). Some soil in the left abutment trough of the North Dam appeared to be saturated, but no free water was found. In addition to the water found at the toe of the embankment, water was leaking around the slide gate in the outlet tunnel at an estimated rate of 0.5 cfs: Additional seepage was entering the outlet tunnel from its roof, and more was probably entering from the floor. Total flow in the outlet channel below the North Dam was estimated to be 2 to 3 cfs, including the water leaking around the closed slide gate.

There was no evidence to indicate that the dams included any type of drain other than the pervious rockfill of which they were constructed; nor is there any instrumentation, such as piezometers, installed in either dam.

2.3.3 Stability

The seepage is not excessive for a concrete-faced, rockfill dam. The rockfill embankments are free-draining and, therefore, eliminate problems normally associated with seepage and uplift pressures. The rock in the embankments and the foundations is sound and is not subject to solutioning. For the types of material used in the embankment, the slopes provide adequate stability. It is our judgment that the stability of both the North Dam and South Dam conforms with criteria recommended in the inspection guidelines (Ref. 1).

2.4 PROJECT OPERATION AND MAINTENANCE

2.4.1 General

Operation and maintenance of Glacier Lake and Dams is the responsibility of the Rock Creek Water Users Association with technical assistance provided by the DNRC and the Forest Service. An agreement between the DNRC and the Forest Service provides for annual maintenance inspections to be performed by the DNRC, with joint inspections by both agencies every three years. Although there is no formal plan for operation and maintenance of the facility, inspection reports dating back many years infer such responsibilities. In general, the reports indicate a history of adequate maintenance. Access to the project is extremely difficult, which limits regular maintenance operations to those which can be performed by hand.

2.4.2 Dams

Maintenance currently is needed on the concrete upstream facings of both dams. Most of the joints on the crest of the dam show spalling, as can be seen in Photo 4. In addition, the one spalled area near the left abutment of the North Dam needs to be repaired (see Photo 3). Efforts should be made to control the leakage around the low-level outlet control gate.

2.4.3 Reservoir

A fairly large amount of debris, mostly dead trees, is partially blocking the spillway approach channel. Records show that this debris has been a problem for many years.

2.4.4 Warning System

There is no formal warning system or plan of action to warn downstream inhabitants or interests in the event of impending dam failure.

CHAPTER 3

FINDINGS AND RECOMMENDATIONS

3.1 FINDINGS

Visual inspection of the Glacier Lake Dams, supplemented by analysis of the project in terms of the recommended guidelines' performance standards, resulted in the following findings.

3.1.1 Size, Hazard Classification, and Safety Evaluation

According to the "Recommended Guidelines for Safety Inspection of Dams" (Ref. 1), Glacier Lake North and South Dams are both classified as intermediate in size with a high downstream hazard potential rating. The recommended spillway design flood (SDF) for this project is the probable maximum flood (PMF). This project can control only about 45% of the PMF volume with the outlet control gate closed, or about 50% of the PMF volume with the outlet control gate fully open. Since the project is capable of controlling only about 50% of the PMF without overtopping and possibly causing the dams to fail, Glacier Lake North Dam and Glacier Lake South Dam do not conform to inspection guidelines with respect to discharge and/or storage capacity.

3.1.2 Dams

Evidence of seepage was found at the downstream toe of the South Dam. No free water was found. Seepage evidence also was found in the left abutment trough of the North Dam. Free water was found emerging from the toe of the embankment in the right abutment trough of the North Dam. Seepage water also was entering the low-level outlet tunnel. The total seepage quantity for the North Dam amounted to approximately 2 cfs.

No bulges or displacements were found in either embankment. The upstream concrete facing was in generally good condition. Spalling was noted at the locations of most joints on the top surface of the concrete. In addition, there was a spalled area on the surface of the facing near the left abutment of the North Dam.

There are no piezometers installed in either dam.

Based on experience with similar structures and materials and on the evidence obtained during the inspection, Glacier Lake North Dam and Glacier Lake South Dam probably conform to inspection guidelines on stability; however, a formal stability analysis does not exist for either dam as required by the inspection guidelines.

3.1.3 Spillway

The spillway was found to be in good condition, with only slight erosion damage evident, along the downstream side of the concrete sill, near its center. In general, the spillway channel appeared to be resistant to erosion. High flows which would accompany a storm of PMP magnitude probably would not

cause excessive damage to the channel nor affect the stability of either embankment.

There is no log boom present to protect the spillway from floating debris, and debris is partially blocking the approach channel.

3.1.4 Outlet Works

Inspection of the outlet works upstream from the slide gate was impossible, as it was under water. The outlet tunnel, downstream from the slide gate was in good condition. Erosion of the floor of the tunnel at the downstream end of the concrete section, as mentioned in DNRC inspection reports, appeared to have been repaired by backfilling with rock. This repair appeared to be performing adequately in preventing undermining of the concrete slab; however, high flows through the gate could cause additional problems in this area. Water was leaking around the slide gate at a rate of approximately 0.5 cfs. The concrete visible at the top of the gate well, on the crest of the dam, appeared to be in good condition, as did the operating controls themselves (see Photo 9). The gate house appeared to be in serviceable condition.

3.1.5 Spillway and Reservoir Capacity

The lake storage and spillway discharge capacities are insufficient to prevent overtopping of the dam during the PMF. This investigation has determined that during the 24-hour PMP storm the project can handle 45% to 50% of the PMF volume, depending on whether the outlet is closed or open, before overtopping and possible embankment failure.

3.1.6 Operation and Maintenance

Operation and maintenance are performed by the Rock Creek Water Users Association with technical assistance provided by the DNRC and the Forest Service. There is no formal operation plan for the reservoir. Water from snowmelt and rainfall runoff is stored in the reservoir and is released from the outlet as needed for irrigation. Consequently, the lake level fluctuates seasonally.

There is no formal maintenance plan for the dams, but the facility has a history of fairly adequate maintenance. Current maintenance needs are detailed in Section 3.2.

There is no formal warning system or plan of action to warn downstream inhabitants in the event of impending dam failure.

3.2 RECOMMENDATIONS

Due to the availability of storage between the normal pool and the dam crest, the present project provides a degree of flood protection to the downstream area. The intent of the recommendations in this report is to maintain or improve project safety, if feasible, without decreasing this existing flood protection.

1. Immediately develop, implement, and periodically test an emergency warning plan for use in the event of dam overtopping.

2. Inspect the condition of the upstream portion of the outlet tunnel and the trash rack at the earliest opportunity when the pool level can be drawn down.

3. At the same time as Item 2, determine the cause of the leakage around the slide gate and repair as necessary.

4. Repair all spalled areas on the upstream concrete facing.

5. Remove all debris from the spillway approach channel. Construct an adequate log boom to prevent debris from blocking the spillway during high pool levels.

6. Conduct more-detailed hydrologic and hydraulic routing studies to better determine the downstream hazard and required spillway capacity. Modify the project as studies indicate.

7. Perform a stability analysis and place it on file, as required by inspection guidelines.

8. Develop and implement a periodic maintenance plan for the dams and appurtenant structures. Because of the remoteness of the project site, the maintenance plan should include frequent condition inspections whenever water is impounded above the natural lake level.

9. Continue all programs for periodic inspections at no more than 5-year intervals; however, a geotechnical engineer, knowledgeable in the design and construction of rockfill dams, should be included in the inspection team.

Prior to performing engineering studies and remedial construction, coordinate work with the U.S. Forest Service and the State of Montana Department of Natural Resources and Conservation to insure compliance with all pertinent laws and regulations.

REFERENCES

1. U. S. Army Corps of Engineers, Office of the Chief of Engineers, Report to the U. S. Congress, National Program of Inspection of Dams, Vol. 1, Appendix D, "Recommended Guidelines for Safety Inspections of Dams", Washington D. C., Department of the Army, May 1975.

2. Howard, K. A., et al, "Preliminary Map of Young Faults in the United States as a Guide to Possible Fault Activity," U. S. Geological Survey, Reston, Virginia, 1978.

3. U. S. Geological Survey, "Earthquake Information Bulletin," Washington D. C., 1973-1978.

4. U. S. Department of Commerce, Earthquake History of the United States, Publication 41-1, Washington D. C.

5. U. S. Army Corps of Engineers, Office of the Chief of Engineers, "Wave Run-up and Wind Set-up on Reservoir Embankments," Engineer Technical Letter No. 1110-2-221.

6. U. S. Department of the Interior, Bureau of Reclamation, Design of Small Dams, Water Resources Technical Publication, U. S. Government Printing Office, Washington D. C., 1974.

7. U. S. Department of Agriculture, Soil Conservation Service, "Average Annual Precipitation in Montana," Portland, OR, 1977.

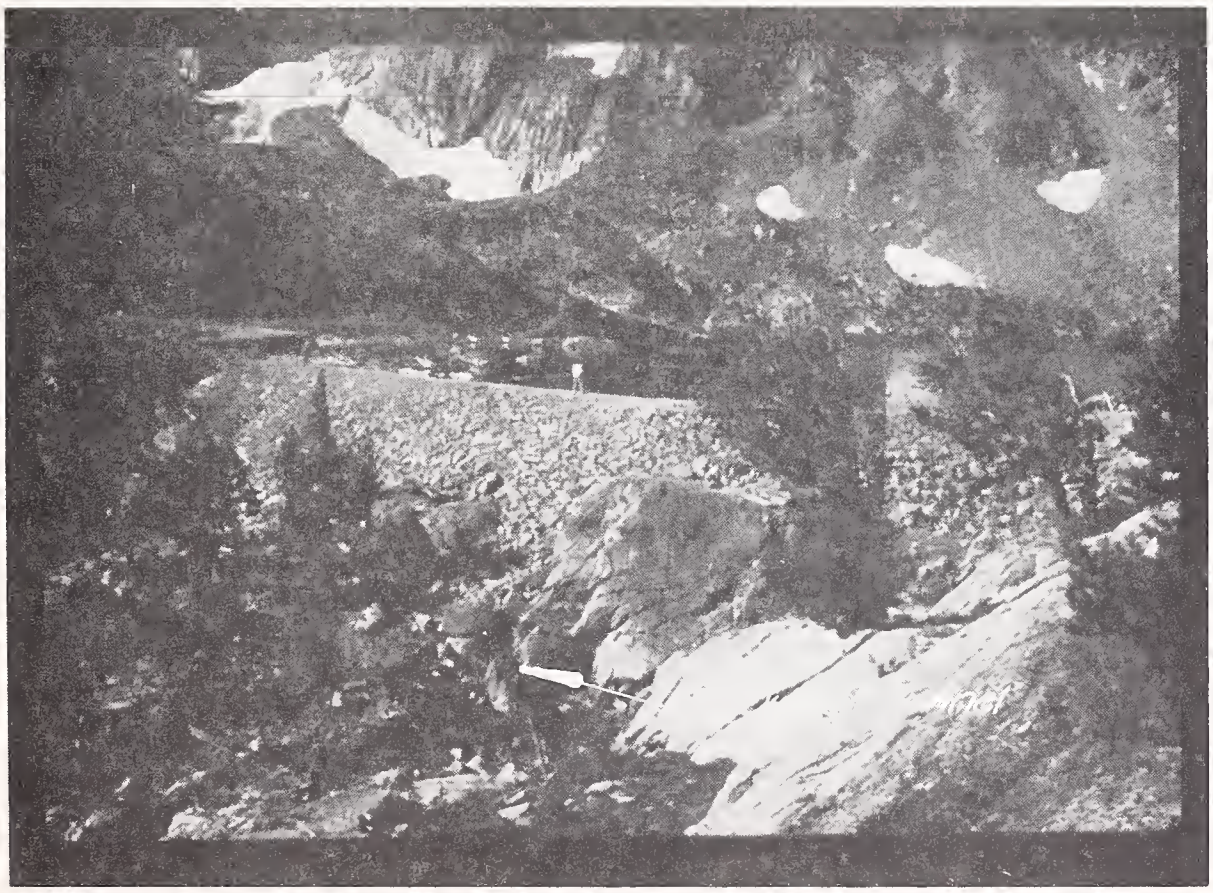
8. Caprio, J. M., "Montana: Average Dates of Freeze," Folders No. 81, 82, and 83, Montana Agricultural Experiment Station, Montana State College, Bozeman, Montana, March 1965.

9. U. S. Department of Commerce, Weather Bureau, Generalized Estimates of Probable Maximum Precipitation for the United States West of the 105th Meridian, Technical Paper No. 38, U. S. Government Printing Office, Washington D. C., 1960.

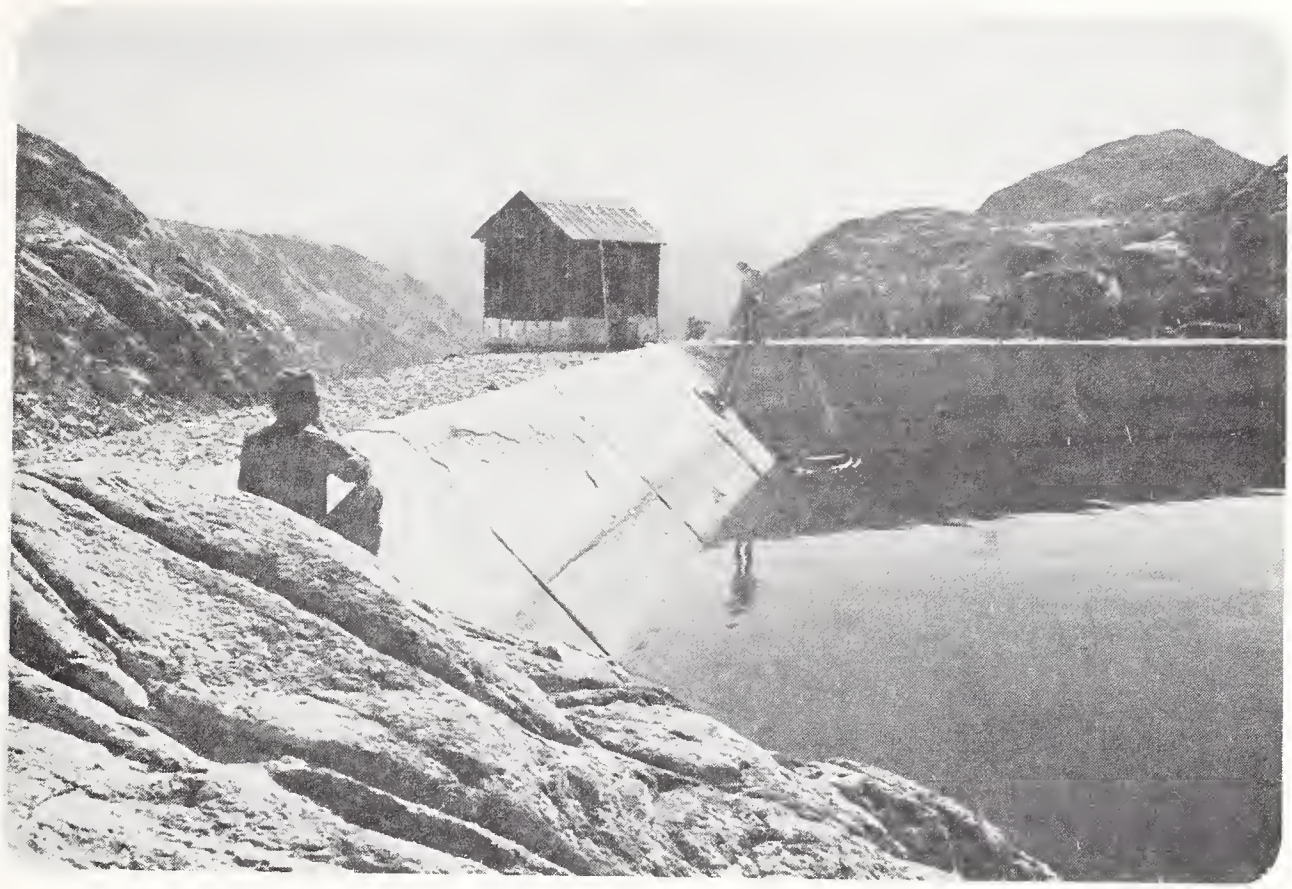
10. U. S. Department of Commerce, Environmental Science Services Administration, Weather Bureau, Probable Maximum Precipitation, Northwest States, Hydrometeorological Report No. 43, Washington, D. C., November 1966.

11. U. S. Army Corps of Engineers, Hydrologic Engineering Center, Flood Hydrograph Package (HEC-1), Users' Manual for Dam Safety Investigations, Davis, California, September 1978.

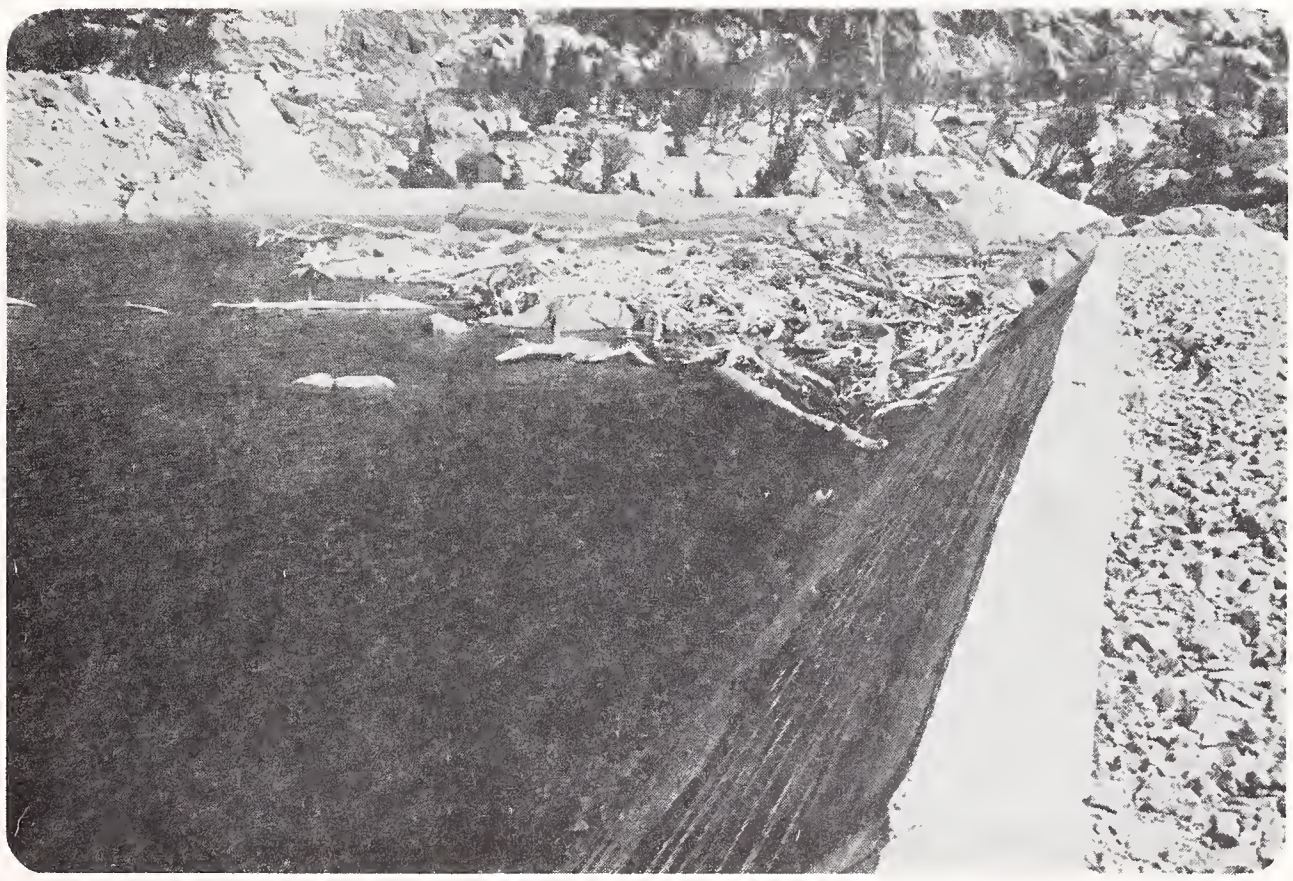
(PHOTO 1) Glacier Lake and Dams, Overview



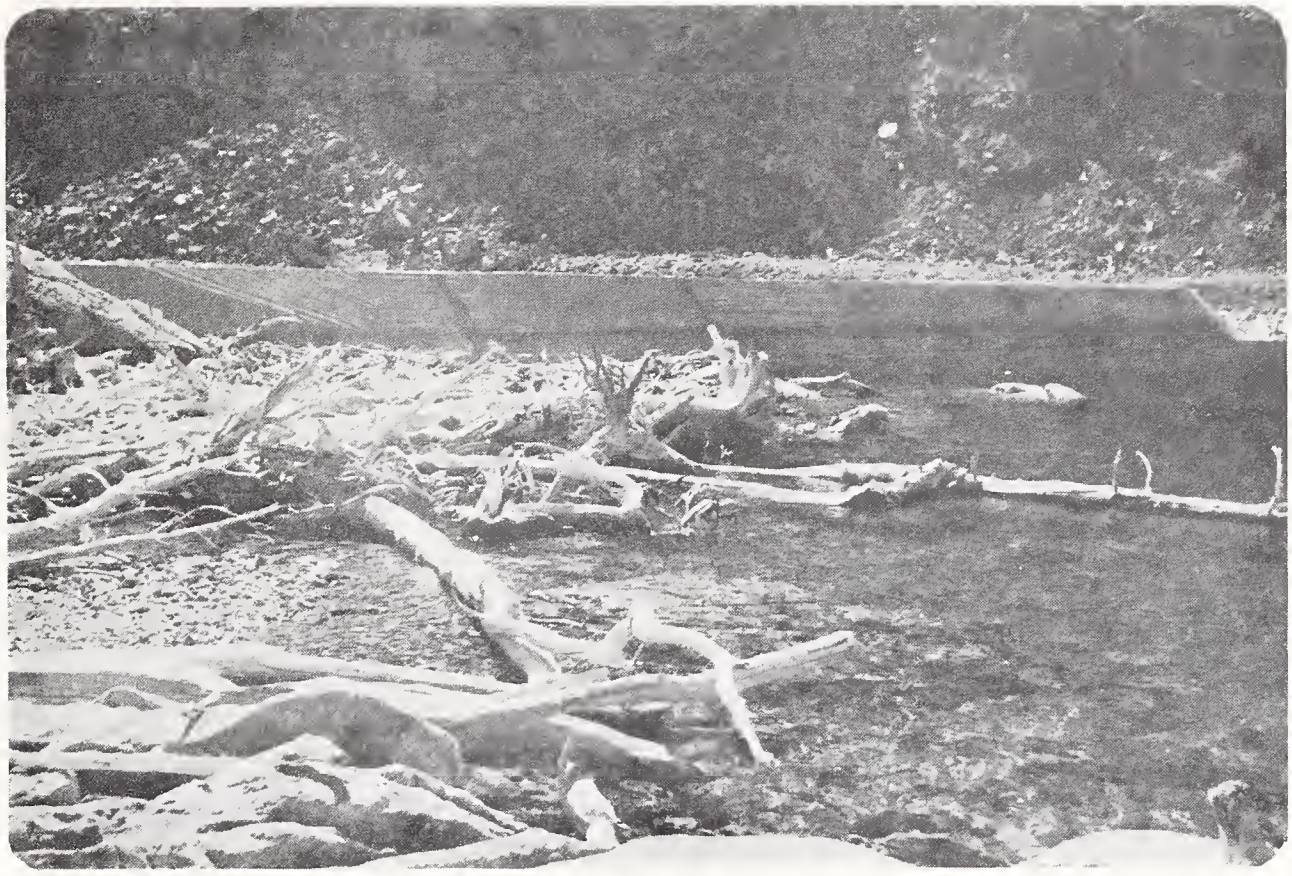
(PHOTO 2) North Dam, Downstream Face and Outlet Tunnel



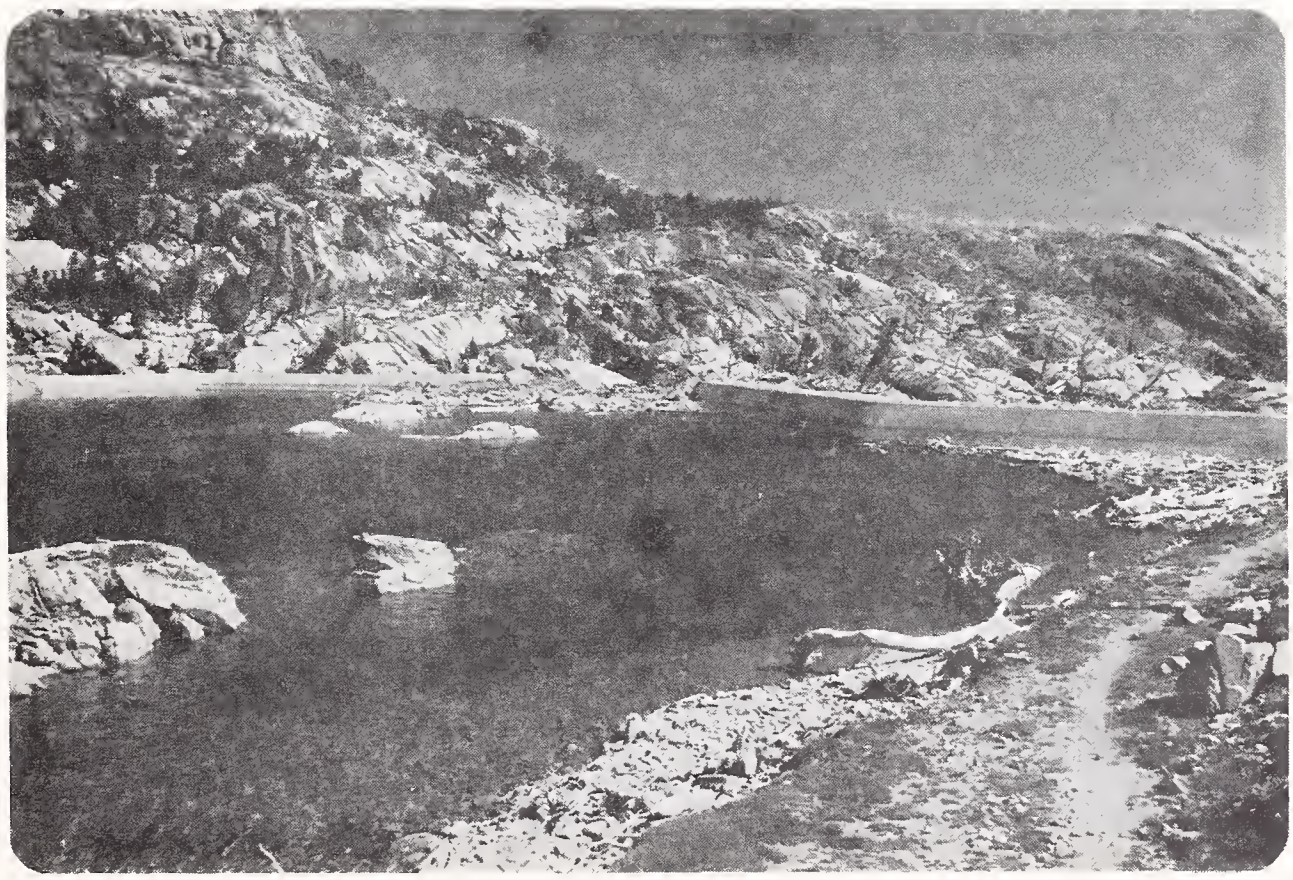
(PHOTO 3) North Dam, Upstream Face from Left Abutment



(PHOTO 4) North Dam, Upstream Face from Crest of South Dam

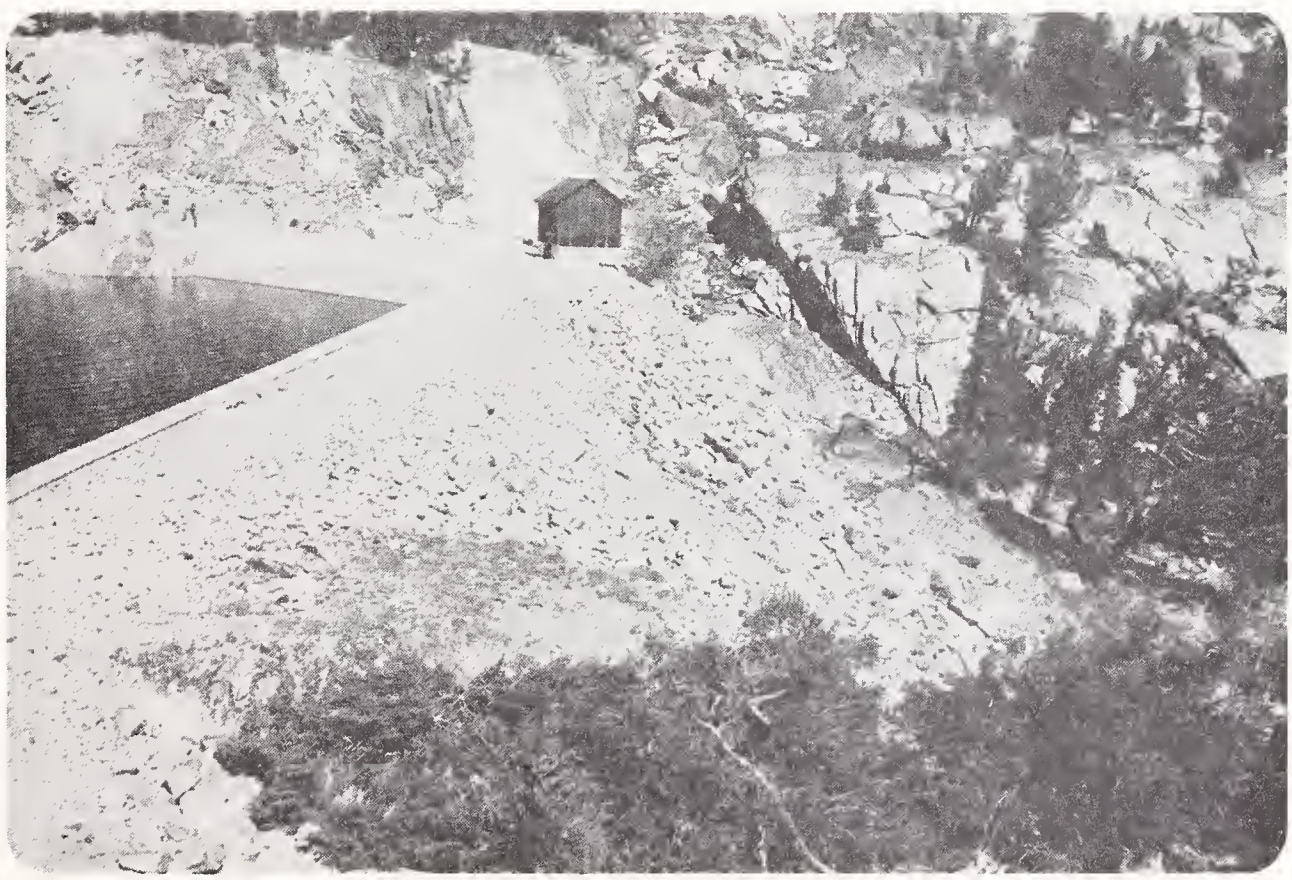


(PHOTO 5) South Dam, Upstream Face from Spillway Approach Channel

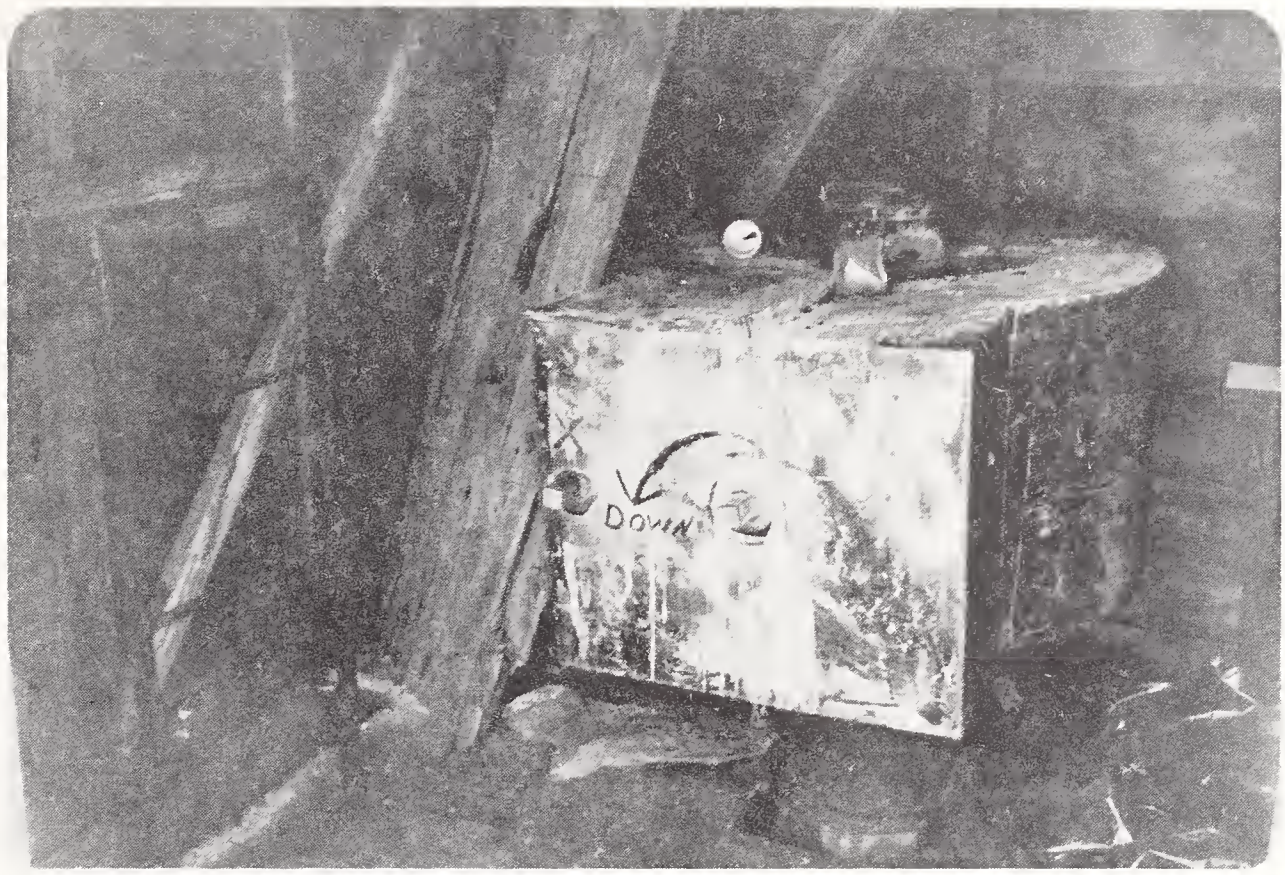


(PHOTO 6) Upstream Faces of Dams from Right Shore

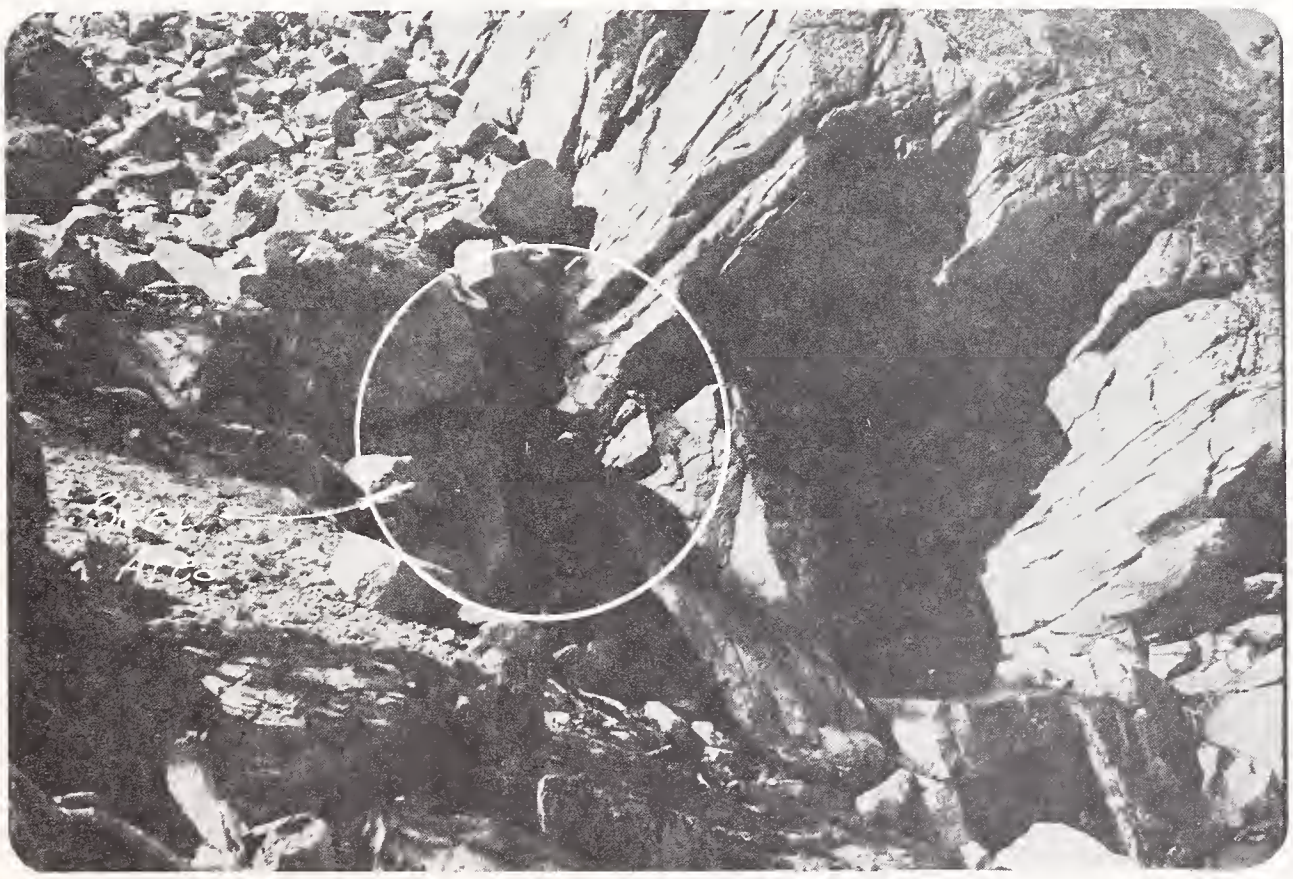
(PHOTO 7) South Dam, Downstream Face
From Spillway Channel



(PHOTO 8) North Dam, Crest and Downstream
Face from Right Abutment

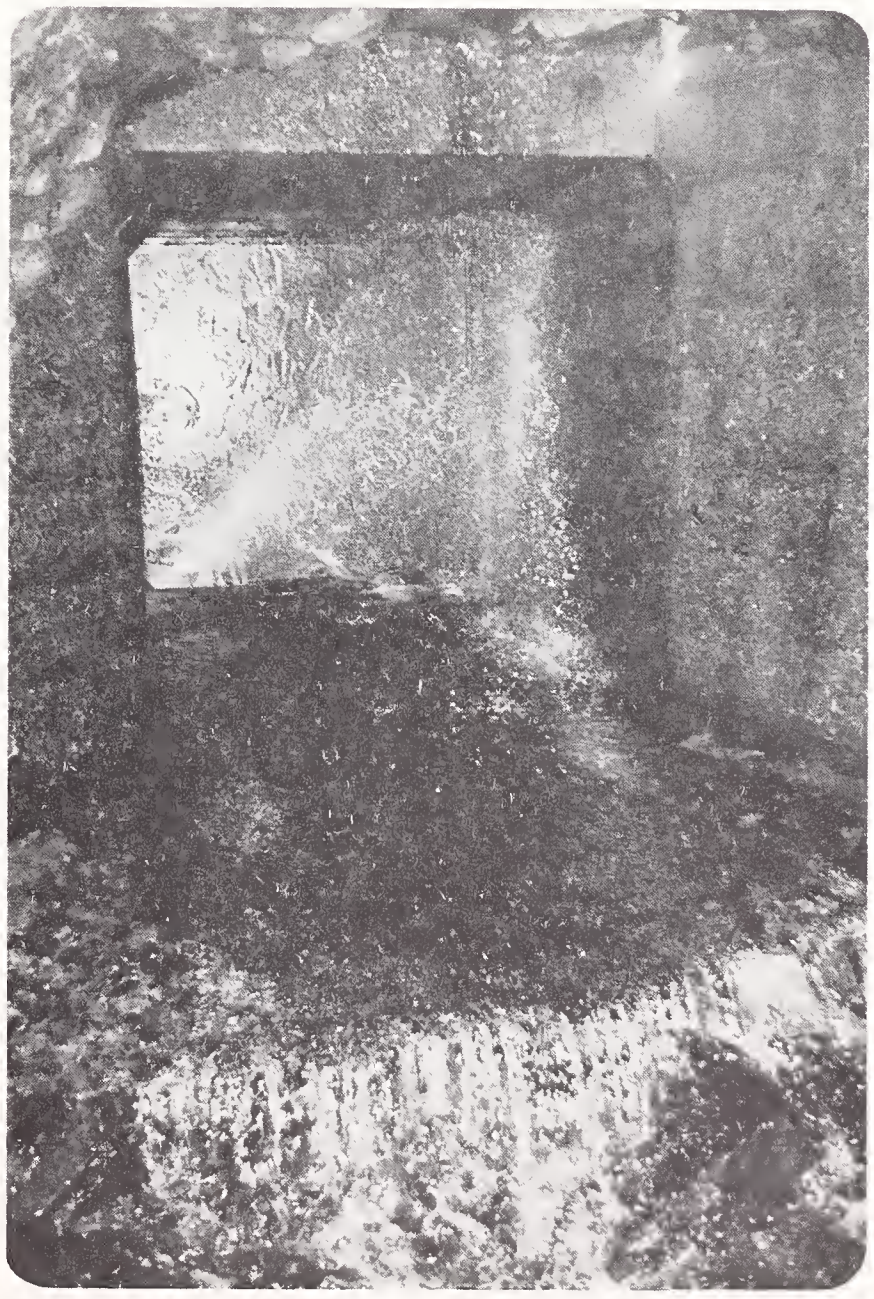


(PHOTO 9) Low-Level Outlet Operating Controls in Gatehouse



(PHOTO 10) Outlet Tunnel, Downstream End Seep Area in Center of Picture

(PHOTO 11) Outlet Tunnel from Downstream End



(PHOTO 12) Slide Gate and Concrete-Lined Portion of Outlet Tunnel

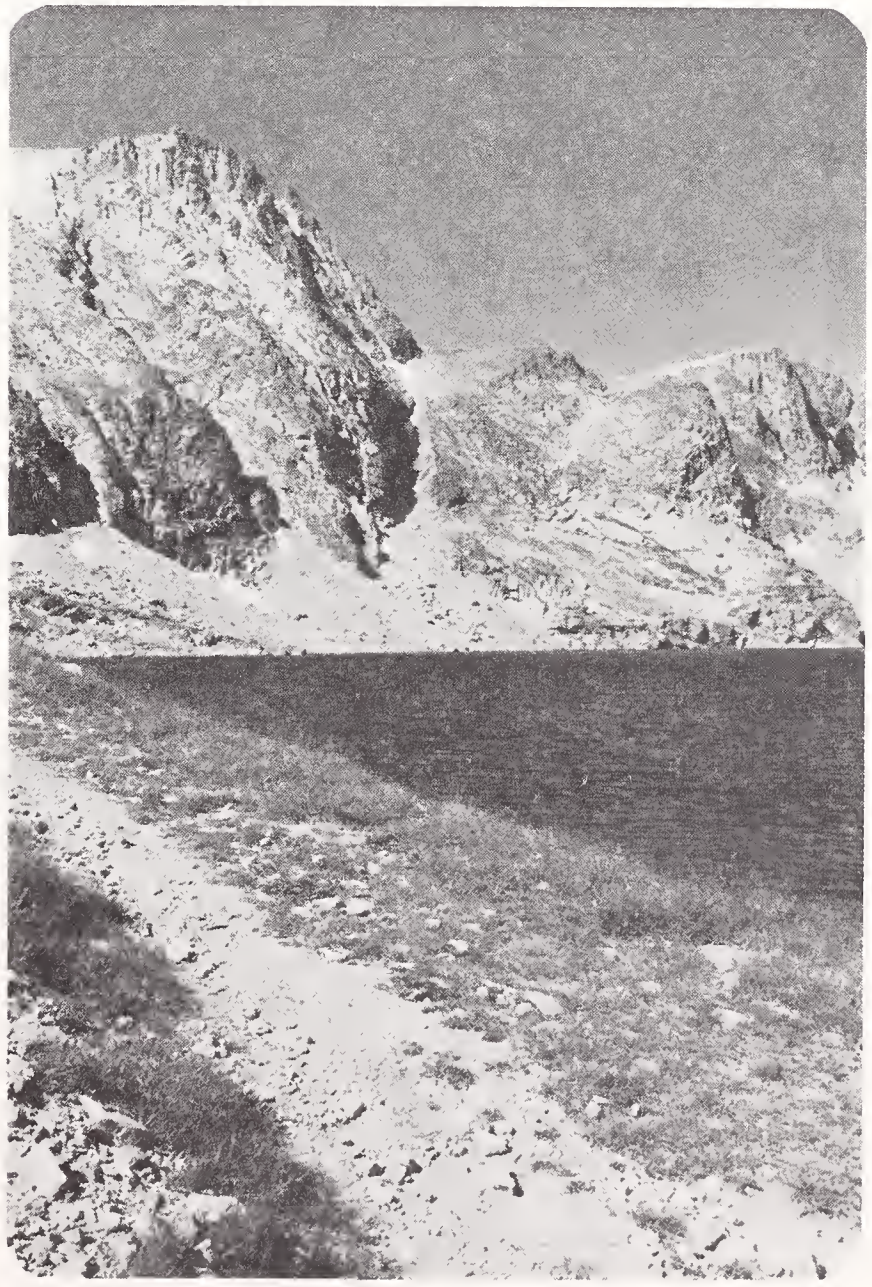
(PHOTO 13) Spillway Approach Channel and Crest Weir from Spillway Exit Channel

(PHOTO 14) Spillway Exit Channel, Looking Downstream

(PHOTO 15) Spillway Crest Weir

(PHOTO 16) Seep Area in Right Abutment
Trough of North Dam

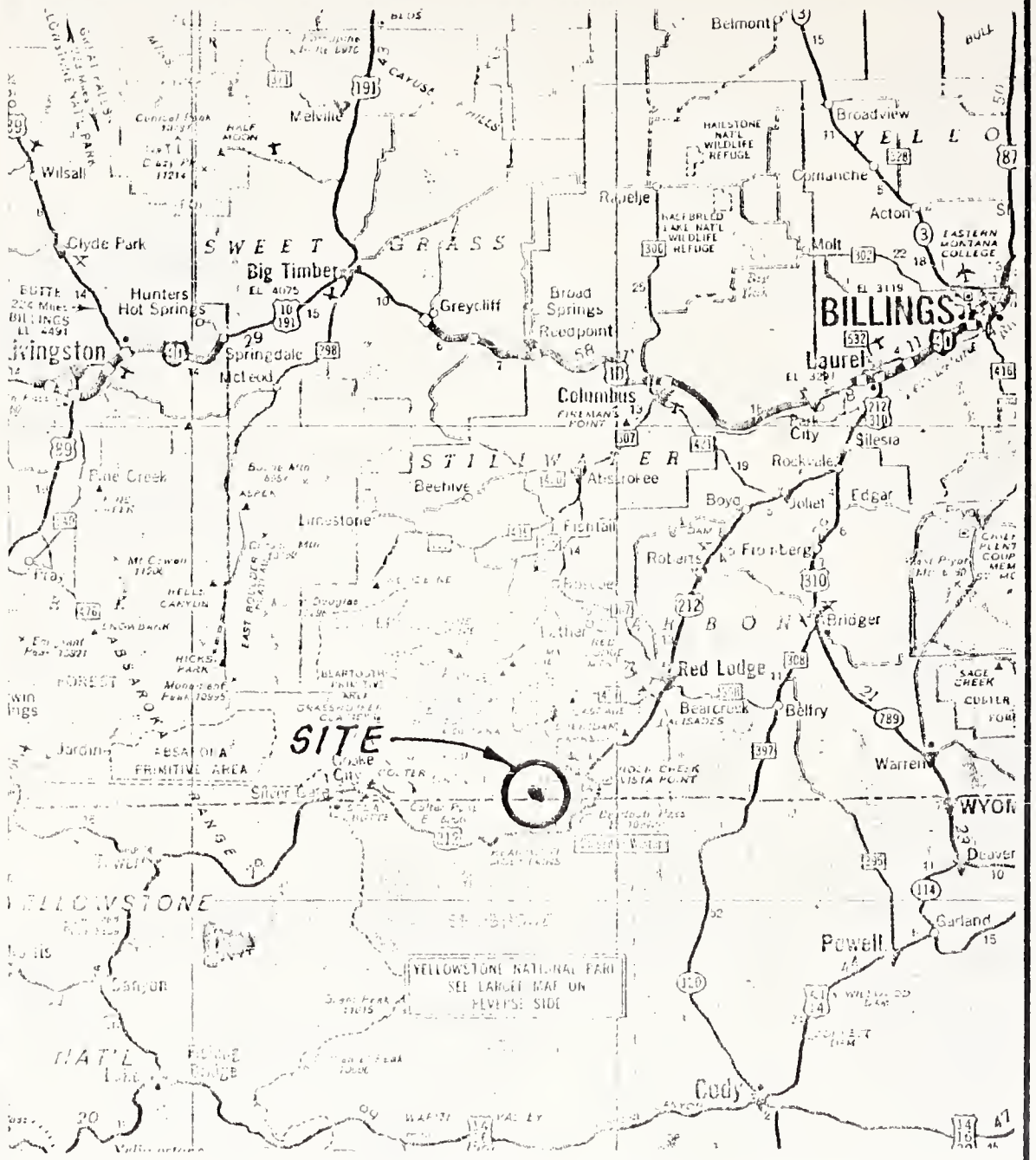
(PHOTO 17) Glacier Lake Drainage Area to the Southeast



(PHOTO 18) Glacier Lake Drainage Area to the Southwest

SITE PLAN

N

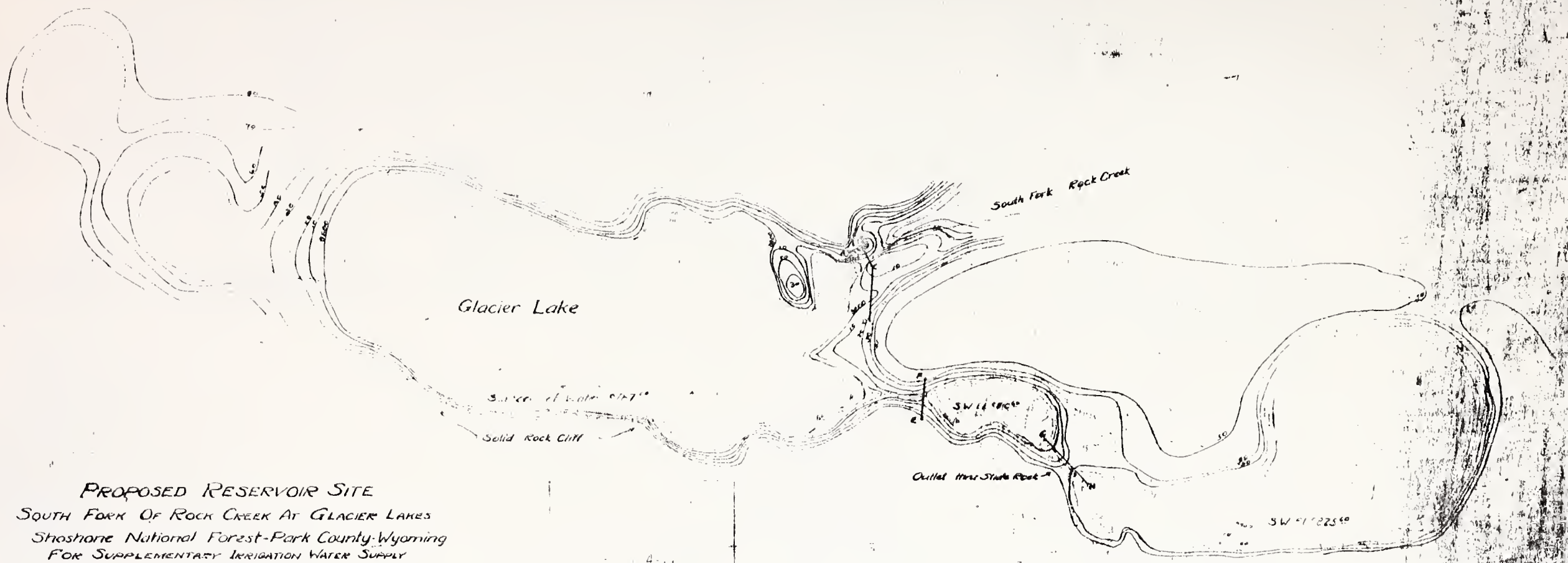


VICINITY MAP

PLATE 1

GLACIER LAKE DAMS (MT-68 & MT-1446)

SITE PLAN & VICINITY MAP



PROPOSED RESERVOIR SITE

SOUTH FORK OF ROCK CREEK AT GLACIER LAKES

Shoshone National Forest-Park County-Wyoming

FOR SUPPLEMENTARY IRRIGATION WATER SUPPLY

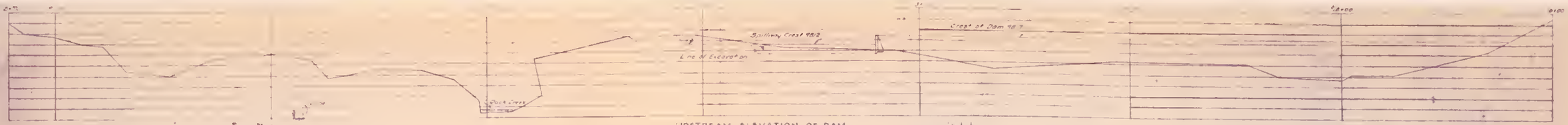
FOR

CARBON COUNTY, MONTANA

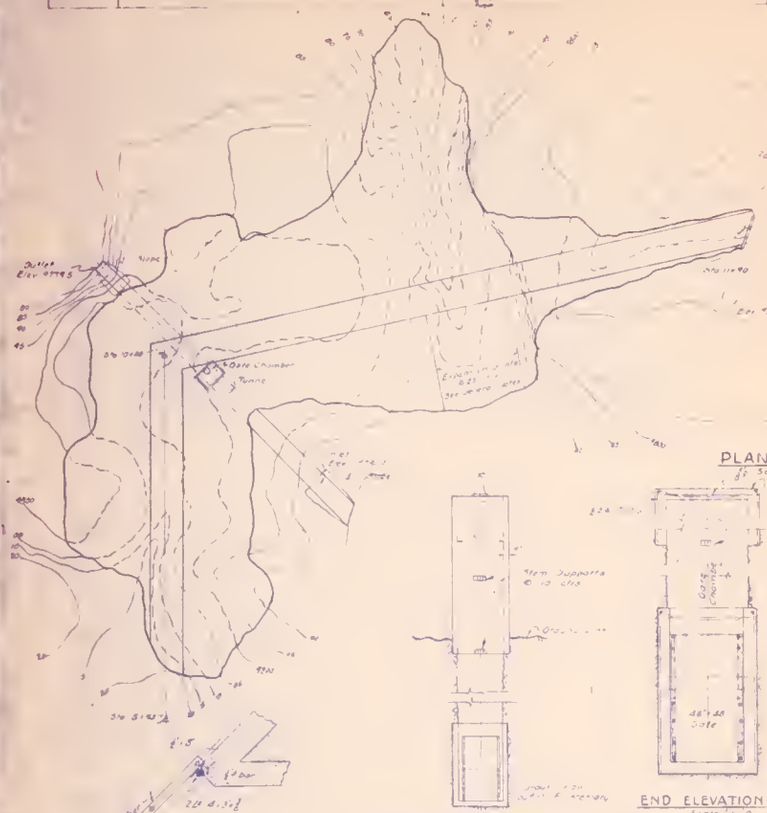
Scale 1"=300'

Survey by County Commissioners - Red Lodge, Montana, June 23, 1933

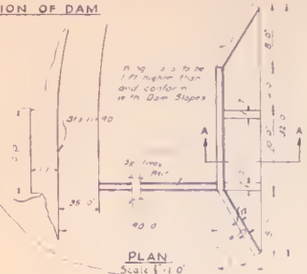
PLATE 2



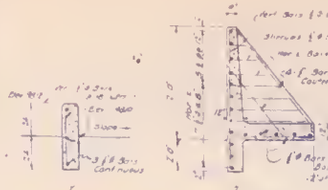
UPSTREAM ELEVATION OF DAM
Scale 1" = 200'



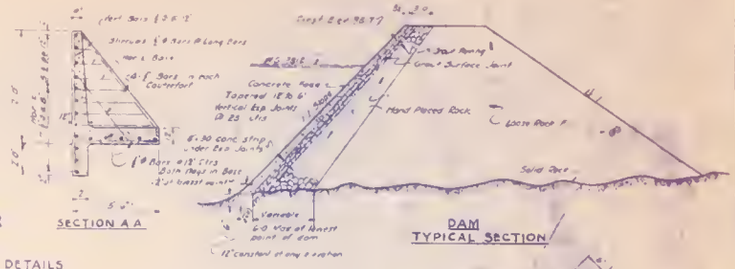
ELEVATION AT STA 11+90



PLAN
Scale 1/4" = 1'-0"



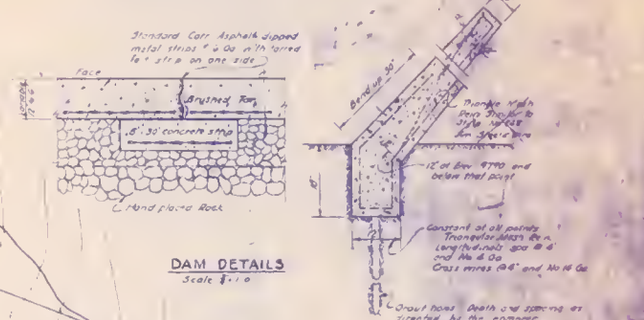
SECTION OF WEIR



SECTION A-A

DAM TYPICAL SECTION

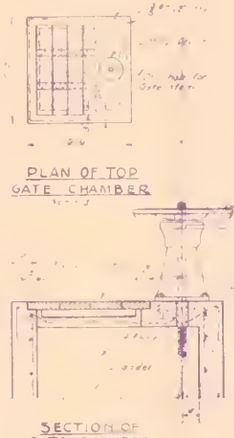
SPILLWAY DETAILS



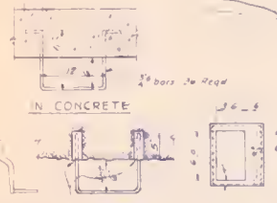
DAM DETAILS
Scale 1/4" = 1'-0"

PLAN OF DAM
Scale 1" = 20'

END ELEVATION-INLET
Scale 1/4" = 1'-0"



PLAN OF TOP GATE CHAMBER
Scale 1/4" = 1'-0"

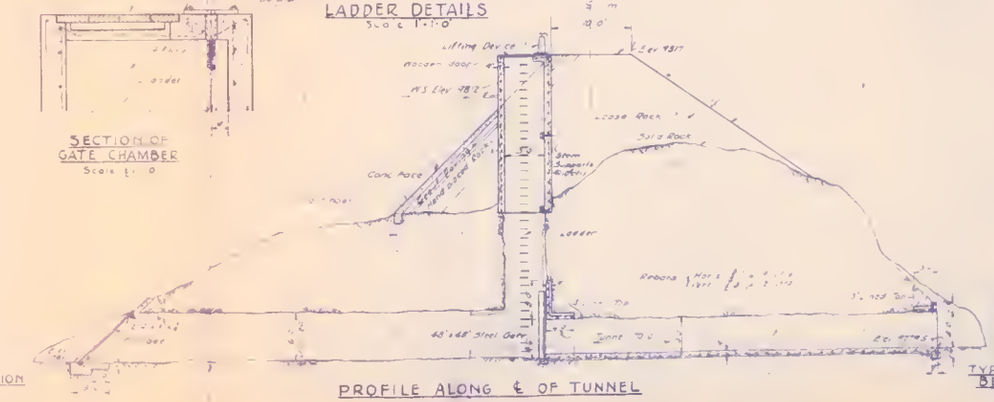


IN CONCRETE

IN ROCK

LADDER DETAILS
Scale 1"=1'-0"

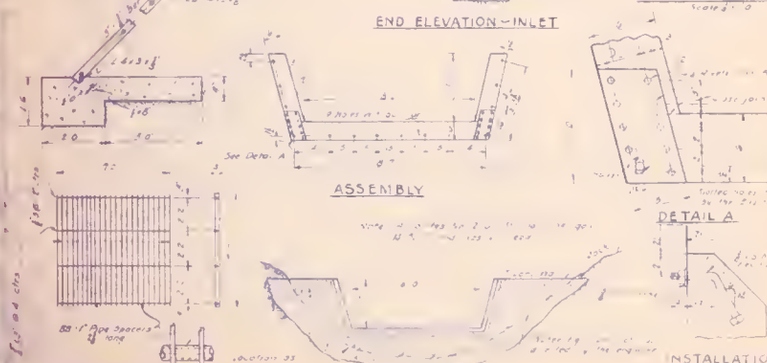
SECTION OF GATE CHAMBER
Scale 1/4" = 1'-0"



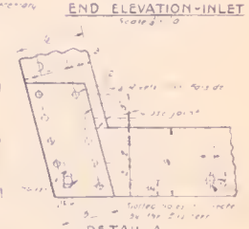
PROFILE ALONG ℄ OF TUNNEL

TYPICAL SECTION BELOW GATE

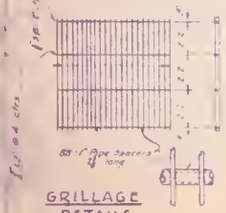
END ELEVATION-INLET



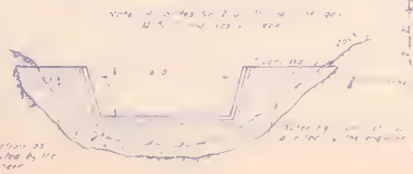
ASSEMBLY



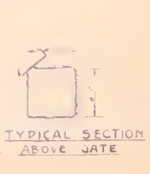
DETAIL A



GRILLAGE DETAILS



INSTALLATION DETAIL



TYPICAL SECTION ABOVE GATE

CIPPOLLETTI WEIR BLADE ASSEMBLY

General Notes

All concrete edges and corners to be chamfered 6". Minimum distance between surface of concrete and sides of reinforcing bars to be 2" unless otherwise stated. All reinforcing bars when bent at ends shall have a minimum bend of 4" square at 90° or a 6" half circle bend.
Reinforcing steel to lap 40 diameters.
Use No 16 Ga wire (Steel Fixe type) for tying throughout.
To splice longitudinal bars, overlap 48 diameters and wrap with No 16 wire.
All reinforcing steel to be bent and lapped around corners at least 30 diameters and tied with No 16 wire.
Expansion joints to be placed normal to ℄ of dam at a maximum of 25 cfs or as directed by the engineer.

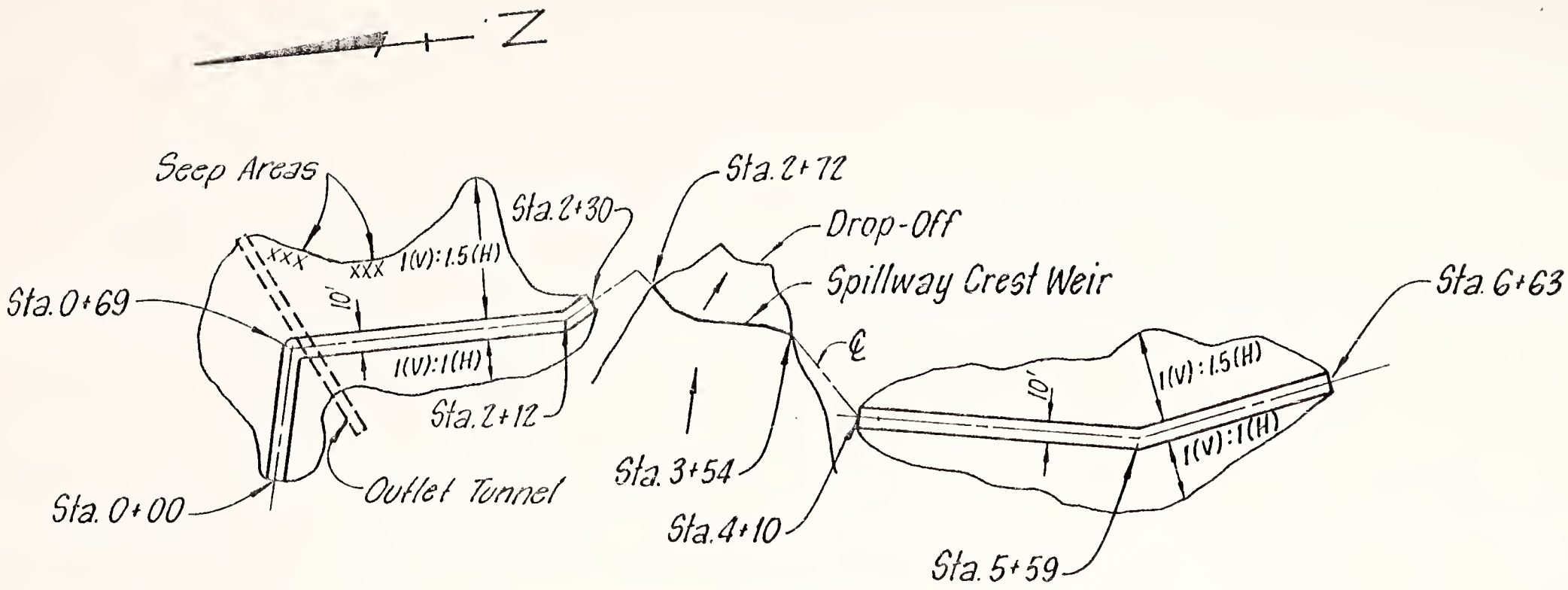
THIS DRAWING HAS BEEN REDUCED TO 1/2 SCALE OF ORIGINAL

PLATE 3

Scale 1/2" = 1' unless otherwise noted

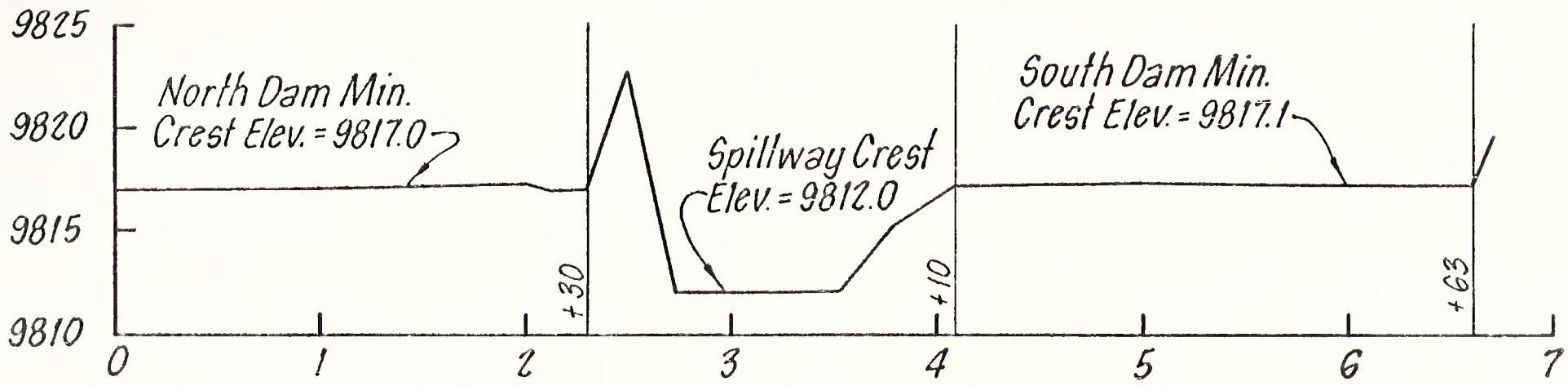
GLACIER LAKE DAM
ROCK CREEK
RED LODGE-ROCK CREEK PROJECT
CARBON COUNTY-MONTANA
STATE WATER CONSERVATION BOARD
JUNE 1935

J.S. JAMES, STATE ENGINEER R.H. FIELD, PROJECT ENGINEER



EXISTING PROJECT PLAN

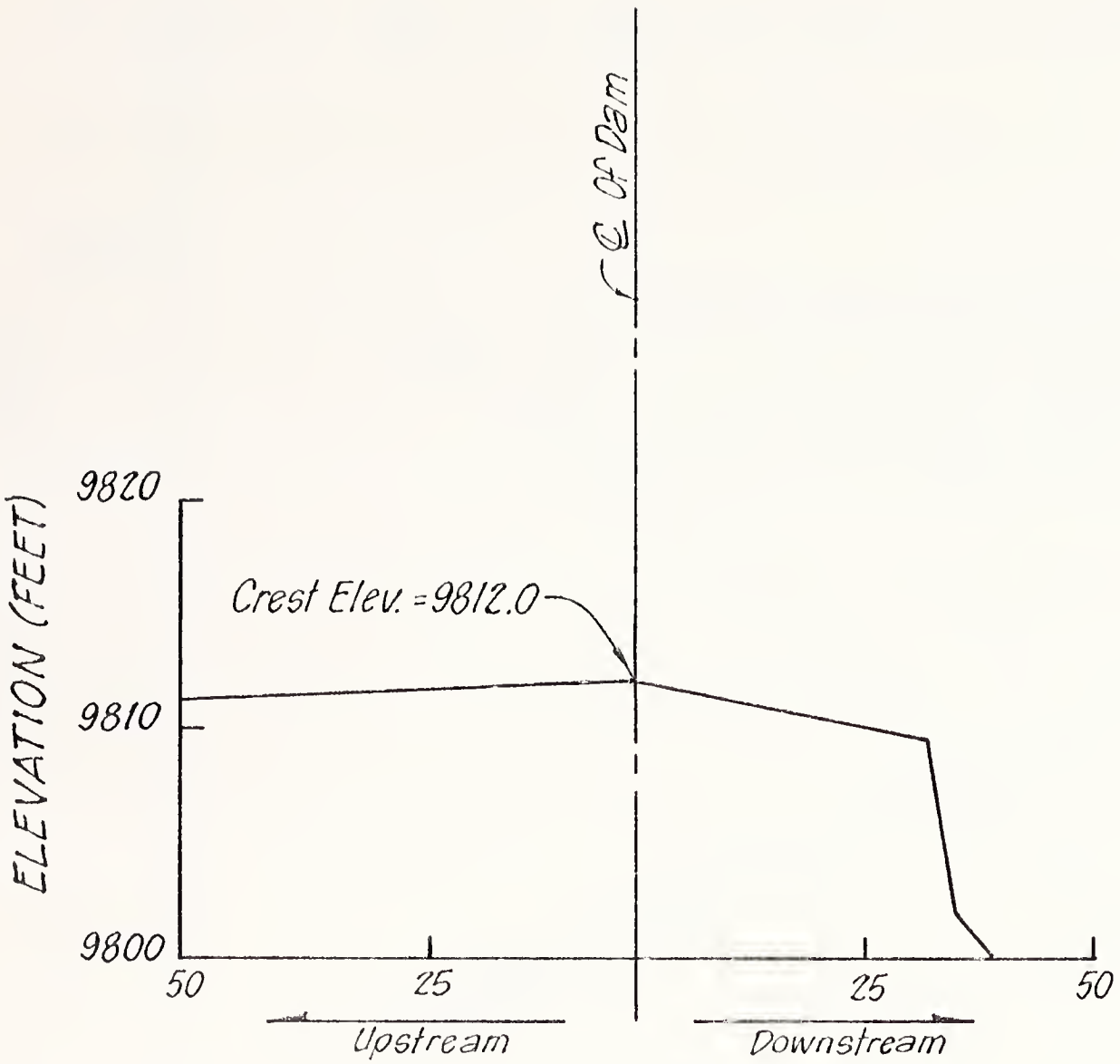
Scale: 1" = 100'



EXISTING CENTERLINE PROFILE

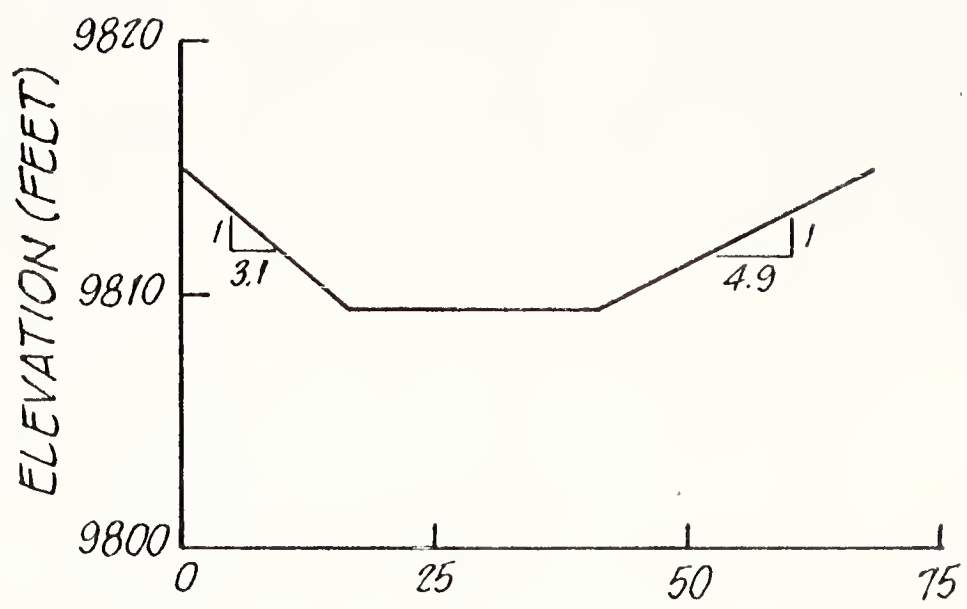
Scale: 1" = 100'(H); 1" = 10'(V)

PLATE 4



SPILLWAY PROFILE

Scale: 1" = 25' Horiz.
1" = 10' Vert.



SPILLWAY CROSS-SECTION
@ 32' DOWNSTREAM FROM CREST

Scale: 1" = 25' Horiz.
1" = 10' Vert.

PLATE 4-A

GLACIER LAKE
ELEVATION-STORAGE
& SURFACE AREA CURVES

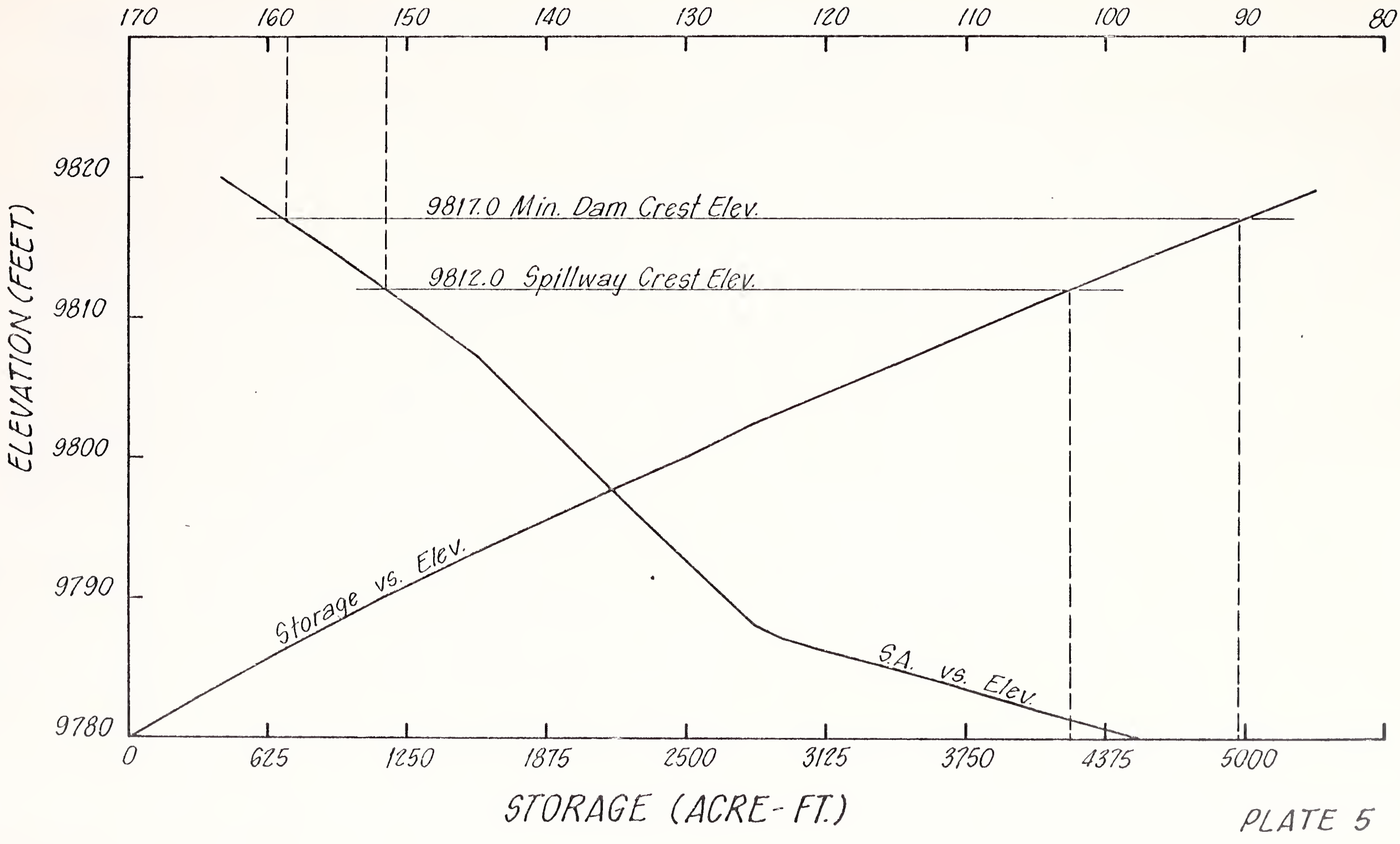


PLATE 5

GLACIER LAKE
SPILLWAY DISCHARGE RATING CURVE

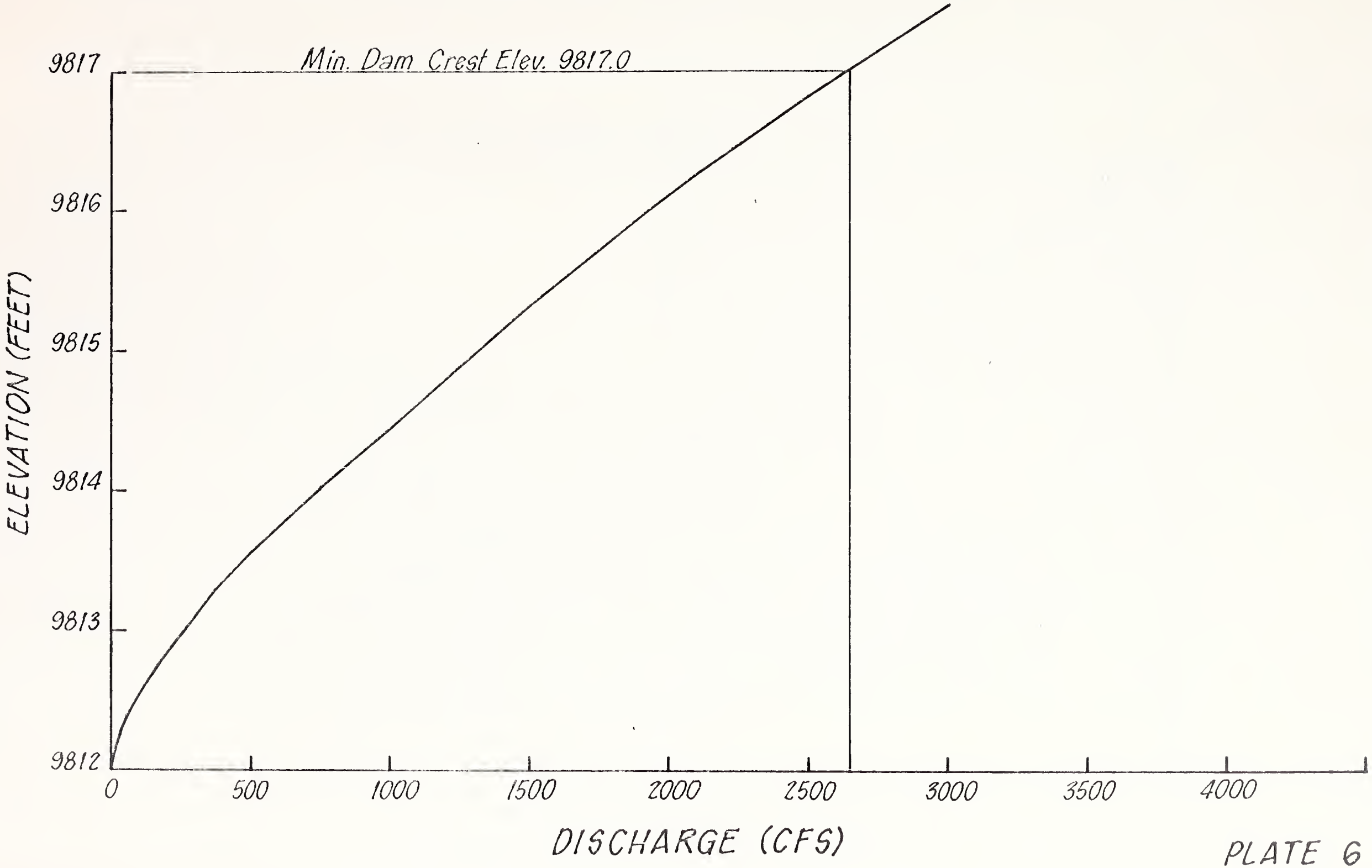


PLATE 6

GLACIER LAKE
LOW-LEVEL OUTLET DISCHARGE RATING CURVE

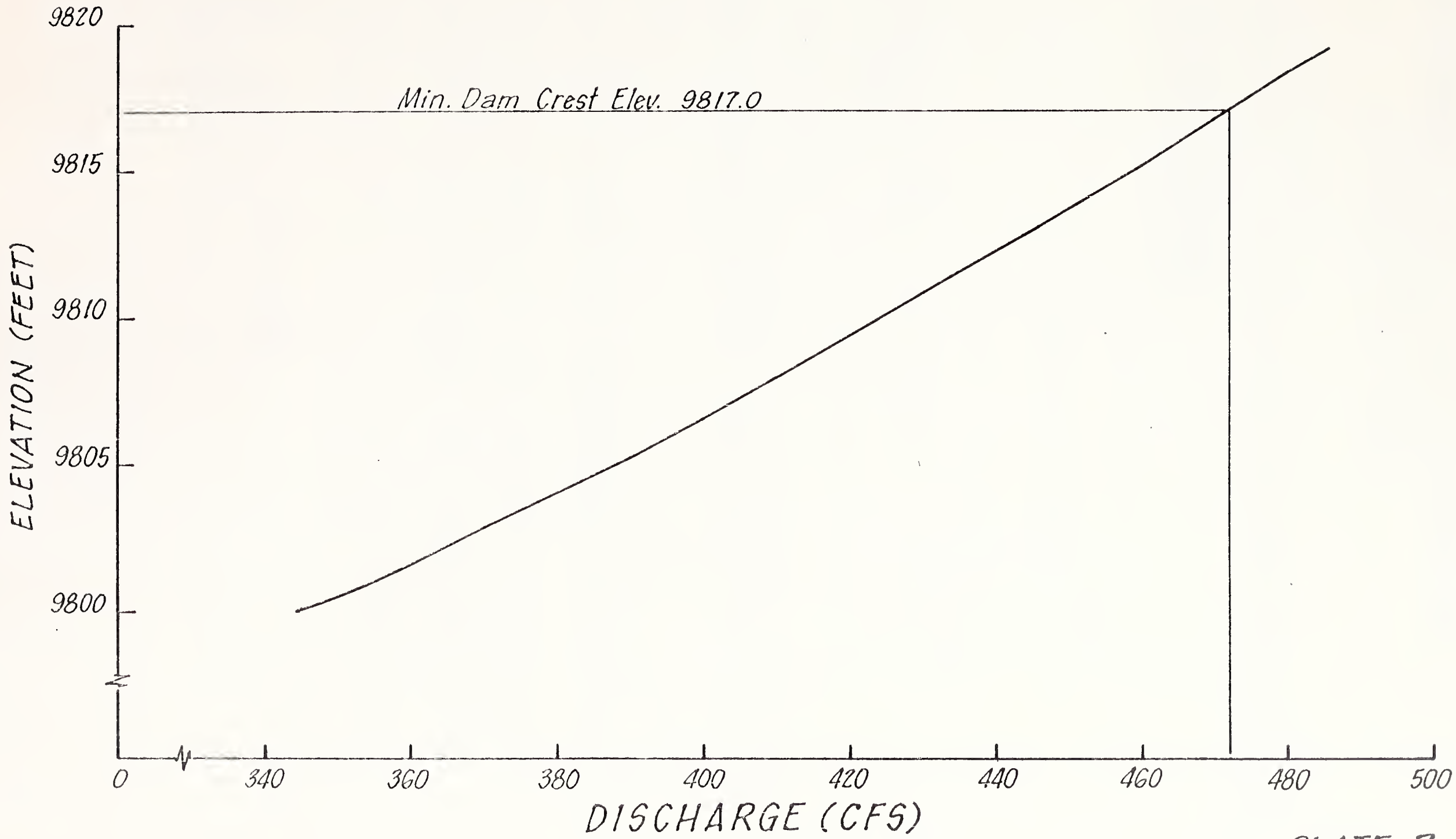


PLATE 7

DEPARTMENT OF NATURAL RESOURCES
AND CONSERVATION
WATER RESOURCES DIVISION

TED SCHWINDEN, GOVERNOR

32 SOUTH EWING

STATE OF MONTANA

(406) 449-2872 ADMINISTRATOR
(406) 449-3962 WATER RIGHTS BUREAU
(406) 449-2872 WATER SCIENCES BUREAU
(406) 449-2864 ENGINEERING BUREAU
(406) 449-2872 WATER PLANNING BUREAU

HELENA, MONTANA 59620

February 27, 1981

Department of the Army
Seattle District, Corps of Engineers
P.O. Box C-3755
Seattle, Washington 98124

Attn: Ralph Morrison

Re: Hoskins-Western-Sonderegger, Inc. Dam Safety Investigation Report on Glacier Lake Dams, North (MT-68), and South (MT-(1446)

Dear Ralph:

We have reviewed the above referenced final draft report. We concur with the findings and recommendations and find that it satisfies the criteria of the Phase I report.

Minor editorial comments have been discussed with your staff, and we understand these will be incorporated in the final report. Copies of the Final Draft report were sent to the Rock Creek Water Users Association, who operate the project, but they did not have any comments of the present time.

Thank you for the opportunity to review and comment on the final draft report on the Glacier Lake Dams.

Sincerely,

Richard L. Bondy

Richard L. Bondy, P.E.
Chief, Engineering Bureau
(406) 449-2864

RB:AT:lj

"AN EQUAL OPPORTUNITY EMPLOYER"

UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
FEDERAL BUILDING MISSOULA, MONTANA 59801

7530
FEB 9 1981

Sidney Knutson, P.E.
Assistant Chief, Engineering Division
Seattle District, Corps of Engineers
P.O. Box C-3755
Seattle, WA 98124

Dear Mr. Knutson:

We have reviewed the draft of the Phase I report for the Glacier Lake Dams and have the following comments:

The report mentions the Montana storm of 1964 approached the PMP in intensity. Your hydrologic criteria for analysis of these structures yielded a runoff in cubic feet per second for each square mile of drainage area of a magnitude 34 times greater than the average of the 30 largest recorded runoff figures for the 1964 flood and is 7 times larger than the peak record of 1,420 cfs/sm. We agree a more detailed hydrologic analysis is necessary.

Sincerely,

Beryl Johnston

BERYL JOHNSTON
Acting Director
Engineering

cc: Custer NF